Trees and Forests of Western United States

By EDWARD JOHN HANZLIK

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FOREST REGIONS OF WESTERN UNITED STATES

PACIFIC COAST

- Douglas Fir
- Western Yellow Pine
- California Woodland
- Redwood
- Sugar Pine - Western Yellow Pine
- Balsam-Mountain Hemlock

ROCKY MOUNTAIN

- Western White Pine
- Balsam-Spruce
- Western Yellow Pine
- Pine-Juniper
- Lodgepole Pine

Blank areas are Treeless

Forest types taken from Natural Vegetation map by Raphael Zon and H.L.Schantz, U.S. Department of Agriculture, Washington, D.C. 1923.

Courtesy-U.S.Forest Service.

Trees and Forests
of
Western United States

BY
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502 CONCORD BUILDING
PORTLAND, OREGON
1928

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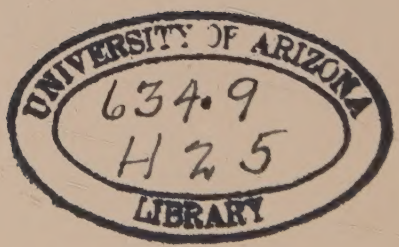

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FOREWORD

THIS book is based upon a series of monographs on western commercial trees, prepared for, and first appearing, in the Four L Lumber News, of Portland, Oregon, the magazine of the Loyal Legion of Loggers and Lumbermen. The original text was written primarily from the viewpoint of the timber owner, logger, sawmill operator, workers engaged in the lumber industry, and users of forest products. At the same time there was included such technical material that use of it could be made by foresters and forestry schools, in botanical courses, in advanced science courses in high schools, by outdoor organizations, and by the layman interested in obtaining a general knowledge of the commercial trees and forests of western United States.

This viewpoint has been followed in the compilation of this volume, the principal idea in mind being to furnish tree and forest facts pertaining to the West such as have to some extent appeared piecemeal from time to time, but had not been presented as an entity before.

In the preparation of this book I wish to express my appreciation for the help and encouragement given me by my friends in the forestry profession and in the lumber industry. I especially desire to thank for their kind aid Mr. W. C. Ruegnitz, President, Loyal Legion of Loggers and Lumbermen; Mr. Hugo A. Winkenwerder, Dean, College of Forestry, University of Washington; Mr. George A. Peavy, Dean, School of Forestry, Oregon State Agricultural College; Major John D. Guthrie, in charge of Public Relations, North Pacific District of the Forest Service; Mr. S. H. Holbrook, Editor, Four L Lumber News; Mr. J. B. Fitzgerald, former Editor, Four L Lumber News; Dr. Helen Gilkey, Professor of Botany, Oregon State Agricultural College; Professor Emanuel Fritz, Division of Forestry, University of California.

I am also very greatly indebted to the United States Forest Service for the use of numerous illustrations, and to the Oregon State Board of Forestry for the loan of the excellent cuts of foliage, cone, and seed characteristics of the principal conifers.

E. J. HANZLIK.

BIOGRAPHICAL NOTE

EDWARD JOHN HANZLIK, author of "TREES AND FORESTS OF THE WESTERN UNITED STATES," is a technical forester by education and experience. He is especially well qualified to write such a book as this. Born in Chicago, Ill., in 1886, and after completing high school, he spent five years in drafting and office work, thereafter studying civil engineering for two years at the University of Illinois.

Coming West in 1908, he entered the School of Forestry, University of Washington, from which institution he received the degree of Bachelor of Science in Forestry in 1912. Due to his uniformly high grades while at the University, and to the intelligent application of his technical knowledge to his work in the forests, he was elected in 1918 to Sigma Xi, the national scientific society. In his undergraduate years he was one of the charter members of Xi Sigma Pi, national forestry fraternity. In 1918-19, he served as director of forestry courses for returned soldiers at the University of British Columbia.

Mr. Hanzlik's seventeen years of experience in the U. S. Forest Service have been wide and varied, and throughout of a technical nature. This experience has included in part such work as yield and tree studies, scaling, tree planting, timber estimating and mapping of forest types, timber management plans, special studies of reproduction, growth, and cut-over lands surveys; all particularly fitting him to prepare a volume on western trees.

In 1922-3, Mr. Hanzlik was awarded a Fellowship by the American-Scandinavian Foundation, at the Swedish Forestry Institute, Stockholm, Sweden. This was supplemented by extensive forestry travel and study throughout Europe.

He is the co-author of the following government publications: "Red Alder of the Pacific Northwest" (with Gibbons and Johnson); "Western Hemlock" (with Oakleaf), and is a frequent contributor to technical forestry and lumber trade journals. He is a Senior Member of the Society of American Foresters, and is a member of the Office of Forest Management, North Pacific District, U. S. Forest Service, in charge of cut-over lands surveys on National Forest areas.

JNO. D. GUTHRIE.

Portland, Oregon, November 26, 1928.

Trees and Their Growth

BOTANICALLY speaking, a tree may be considered as a woody plant having a well-defined stem at least 8 feet tall and not less than 2 inches in diameter, with a more or less definitely defined crown. It is sometimes difficult to draw the distinction in all cases between shrub-like trees and tree-like shrubs; however, from a forestry standpoint, where commercial trees are the main consideration, this matter of drawing a fine distinction is of little practical value. For commercial purposes, taking the manufacture of lumber as a criterion, a tree is hardly considered in the practice of forestry unless it will attain under average growing conditions in its natural or extended range, a size of at least 14 or 16 inches in diameter and 80 or 100 feet in height.

In the study of the life of a tree we come into contact with the study of botany. Botany may be defined as the science which treats of plants, and the study of trees and tree-life is a part of this science of botany. In considering the structure of the individual plant and its parts we find the following botanical divisions:

Plant Morphology — which covers the form and structure of plants in their organic parts, such as the roots, stem, leaves, etc.; or in other words, the study of the organs of individual plants.

Plant Physiology — which treats of the plant in action; how it lives, breathes, feeds, grows and reproduces. It considers the raw materials out of which the plant is made, the process of manufacture, and the methods of distribution throughout the plant.

Plant Geography — is a study of the distribution of the various kinds of plants over the surface of the earth.

Plant Ecology — treats of the relations of the plant to the conditions under which it lives, together with the origin and development of plant associations. The effects of soil, climate, animals, associating plants, habits and structure are also studied. A study of this branch of botany brings out that the plant is not an organism of fixed form structure, distribution and habits; but that plants undergo changes in all these, varying in one way or another under the influences of changing conditions of life.

Economic Botany — is a study of the uses of plants to man.

Of the above branches of botany, plant morphology and plant physiology take precedence in the study of trees in their structure, form, life and habits.

The Life and Structure of the Tree

The principal parts of a tree are the roots, stem and leaves.

In its development from the seed to maturity and throughout its entire life, except for a comparatively small amount of food in the seed, a plant in order to live must extract the raw material from the earth and the atmosphere, and then manufacture its own food. This work is done by the roots and the leaves, and the food is then distributed to various parts of the tree by means of the stem.

The *roots* have two principal functions in the life of a tree. First, they serve as a means of absorbtion of water and raw food particles from the soil; second, they act as an anchor to the bole and crown in the ground so that they can withstand the wind and re-

main in an upright position. The raw foods, which are in the form of mineral salts in solution, are absorbed through the minute root hairs attached to the extremities of the roots. These tiny root hairs are extremely thin-walled, coming out from and opening into the epidermal, or outer cells. These walls are very thin, and no holes or pores are visible even under the highest powered microscopes; but through the power of osmosis, or the process of attraction by which fluids pass through a membrane, this passage is affected. The raw food particles are then transferred upward through the stem to the leaves for changing into food.

The Stem or Bole

The stem or bole of a tree also has two principal uses; it serves the important purpose of supporting the crown, thereby lifting the leaves up into the sunlight, where they can best do the work of preparing the food; and second, it is a means of transportation of water and raw food particles between the roots and the leaves, and the finished foods from the leaves to the various portions of the tree.

The structure of the bole is usually considered to be of solid material, whereas in reality it is composed of numerous cells and ducts and vessels through which the food has its movement. To the naked eye these cells in many species are not visible, but with the aid of an ordinarily strong microscope they are readily seen.

The principal parts of the bole of a tree are the central portion, or the wood, and the outer portion called the bark. In these two divisions there are respectively wood cells and bark cells through which raw materials and foods are transferred.

There is a marked variety of functions among the various groups of cells that make up the bole of a tree, a few of the primary ones and their uses being as follows:

The *pith* forms a large portion of the stem of young trees, it being a part of the tissue of comparatively simple structure. There are a number of ducts or vessels, or bundles of tubes for the transference of food, which lie between the pith and the outer edge of the woody tissue. These bundles later, as growth occurs, become larger and are gradually connected by a growing layer of tissue which then becomes the *cambium,* or growing tissue. In older trees the pith becomes of no importance and occupies a relatively insignificant proportion of the stem.

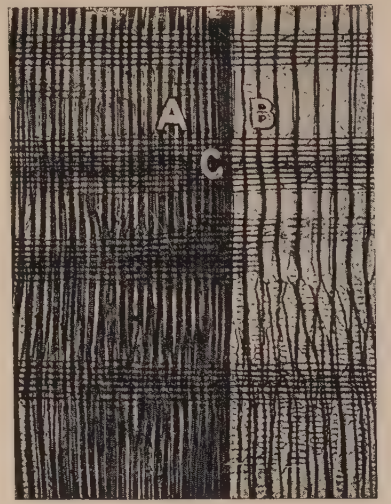
The *cambium,* or growing tissue, is the portion in which the annual growth of the tree takes place. It is composed of thin-walled cells, which rapidly divide into others, forming wood cells on the inner edge or toward the center of the tree, and bark cells on the outer edge, or the inner bark.

The *medullary* or *pith rays* are horizontally placed cells extending outward from the pith to the inner bark. They serve as channels for the transference of food across the stem radially to the cambium. They are also of use in storing food which is laid up in the summer and fall for use in the following spring.

Vessels or *ducts* are cells vertically arranged through the stem for the distribution of water upward into the top of the tree, and to the medullary rays.

The *wood cells* are the supporting tissues of the stem, those of the sapwood in addition serving as a means of carrying most of the water from the roots to the leaves and other portions of the tree. These woodcells comprise by far the greater part of the stems of the older trees, becoming proportionally greater as each annual ring is added. They extend vertically,

RADIAL SECTION OF SITKA SPRUCE MAGNIFIED 50 TIMES



NO. 1

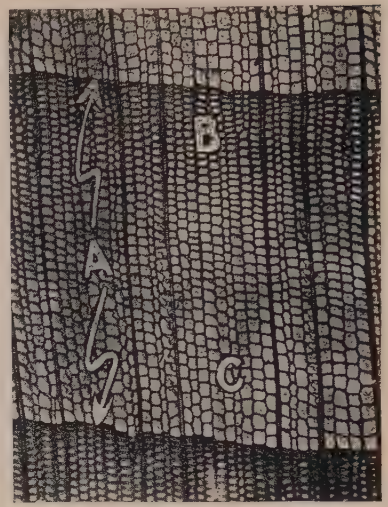
A—Summer wood. B—Spring wood. C—Cross lines show medullary rays.

TANGENTIAL SECTION OF SITKA SPRUCE MAGNIFIED 50 TIMES

NO. 2

Medullary rays are here shown as black lines with occasional white-dotted islands.

CROSS SECTION OF SITKA SPRUCE MAGNIFIED 50 TIMES



NO. 3

A—Dark lines from left to right are limits of annual ring. B—Summer wood. C—Spring wood.

parallel to the pith, and are four-sided in cross-section, some almost square and others rectangular in shape. Around each cell is a hard wall of varying thickness; usually those in the summerwood, formed in the latter part of the growing season, have thicker walls than those in the springwood which are formed in the spring of the year. When first formed wood cells or cell walls are quite soft and easily crushed, but as the season advances they become harder and rather firm, of a somewhat yellowish color. These are then said to be *lignified,* and the process of hardening is called *lignification.*

Sieve tubes are found in the inner or growing bark tissue, and are the most important portion of it. They serve as a means of transferring manufactured plant food from the leaves downward toward the roots, and thence through the medullary rays to the growing tissue of the cambium.

Upon the *green outer layer* of bark of young trees are the *lenticels.* These are round openings of small size which serve to admit air to the cambium, and also for the escape of excess moisture. These lenticels are best observed on young cherry trees or birches.

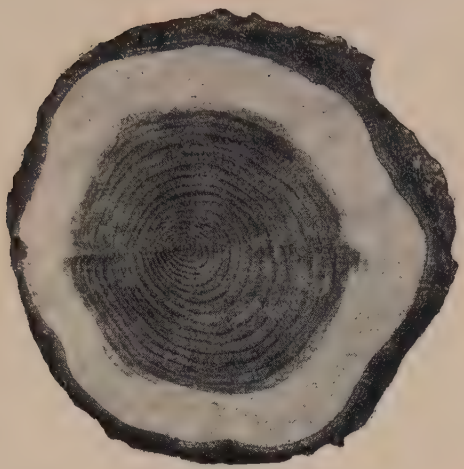
The outer layer of bark in the older trees is quite inactive in the process of food manufacture or its distribution. Its principal and very important use is that of protecting the growing tissues from injury. The corky outer substance is a good protection from mechanical abrasion; it is also a very good non-conductor of heat in the case of fire. The bark of older trees is of more value for these purposes than in younger trees; also some species have a thicker and more resistant bark than others. Very good examples of the thick-barked species are the old growth trees of Douglas fir and redwood, while characteristically thin-barked trees are the western red cedar and the Alaska cedar.

The Leaves

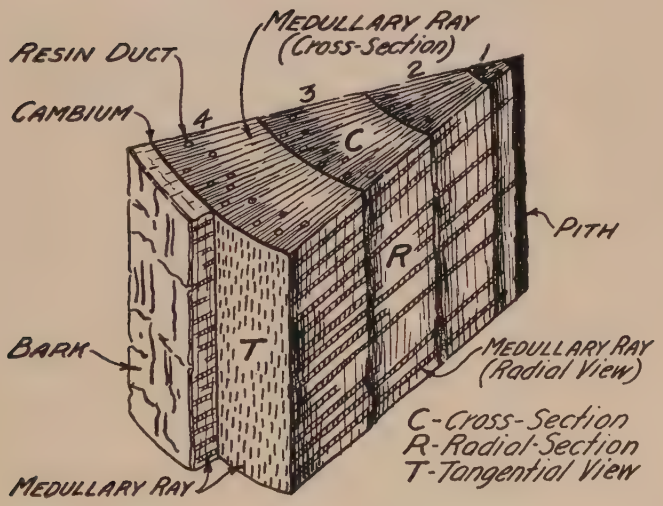
The leaves are a rather complicated system of bundles of tubes composed of a number of ducts for transferring food. These also form the veins in the broadleaf trees, constituting a framework by which the leaf is supported and strengthened. Over and around these veins lies a mass of green pulpy material, called the *parenchyma.* The whole leaf is covered with a protecting layer, called the *epidermis,* which serves as a mechanical protection to the parts beneath, and also prevents excessive evaporation. The function of the leaf, as with the roots, is to aid in the absorbtion of raw materials, and in addition in the preparation of the food.

The substances required by the plant for nutrition are composed of the chemical elements, namely: carbon, hydrogen, oxygen, nitrogen; this group of four composing by far the greater part of the weight of a plant; and to a lesser degree sulphur, phosphorus, potassium, calcium, magnesium, and iron. The carbon and oxygen are absorbed from the air by the leaves, the hydrogen from water, and the others from the soil in the form of salts in solution. A lack or a shortage of any one of these essential food elements results in plant growth being stunted and unhealthy.

The function of the leaves is of the greatest importance to the tree. There are four principal acts connected with their work: (1) photosynthesis, or the manufacture of carbohydrates (starches and sugars) from carbon-dioxide and water; (2) respiration, or the taking in of oxygen; (3) assimilation, or the transformation of the absorbed or manufactured food into materials of its own tissues; and (4)



Section through bole of fast-growing tree, showing the dark heartwood and the light sapwood and the annual rings.



PORTION OF A FOUR YEAR OLD STEM OF PINE
(Enlarged)

transpiration, which is the process of giving off carbon-dioxide and water which no longer are required. Transpiration is similar to human perspiration with the difference that in plant life excess materials are thrown off only through the leaves.

Tree Growth

The growth of a tree takes place through the functioning of its various parts, which may be summed up in the following manner:

1. The buds, root-tips and cambium layer are the growing parts of the tree.

2. The roots, through osmosis, absorb water containing a small quantity of mineral matter in solution; this is carried upward through the sapwood of the stem to the leaves.

3. Air supplies the carbon, which is the principal food of the tree. This is taken in on the under surfaces of the leaves.

4. Food, which is obtained from the air and soil, is prepared by the leaves, which is then carried from the leaves to the cambium layer by means of the cells in the inner bark. Light and heat are necessary for the chemical changes which take place in the preparation of the food.

5. The leaves give off carbon-dioxide and water which no longer are required in the process of food preparation.

6. The breathing pores of the entire tree — on the leaves, twigs, branches, trunk and roots take in oxygen.

7. Tree growth in height and in spread of branches takes place by the addition of the manufactured food to the outside of the wood portion of the twigs and inside the bark.

8. Diameter growth of the bole takes place by the addition of annual layers of material between the outer edge of the wood and the inside of the bark shell; this hardens at the end of the growing season and then becomes *wood*. The soft substance between the wood and the bark is the *cambium layer*.

Thus, in the process of growing, a tree covers itself entirely from the tip of each branch to the tip of each rootlet with a complete new layer of wood each year.

Classification of Plants

THE classification of plants is an attempt to express kinship, or what among human beings is called blood relationship, which is believed to exist among them. To illustrate this principle the pines may be taken as an example. All of the pines have as a principal characteristic that their fruits are in the nature of a *scaly cone*, and the seeds are borne *naked* at the base of the scales and ripen the *second* season. The leaves are *needle-shaped, evergreen,* and in clusters of usually from *two* to *five*. The five-leaved pines are the white or soft pines; the others are called the yellow, or hard pines. Any tree with the foregoing characteristics is a pine.

The spruces, firs, hemlocks, and larches are similar to the pines in many respects, but differences are noted that in the latter species it takes only one year to ripen the seeds, while the foliage either occurring singly as in the spruces, firs and hemlocks, or in many-leaved clusters (from 12 to 40 in a cluster) as in the larches. Other evergreens, or conifers, as the cedars, junipers and cypresses have awl-shaped or scale-like leaves, which are not in clusters.

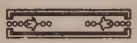
All the different cone-bearing trees are distinct kinds as broadly differentiated in the foregoing, but they are grouped together in one general class because their seeds are borne naked, or not enclosed in a nut or berry, upon the scales of woody cones. Most commonly these are known as evergreens, or softwoods, for the reason that with but few exceptions, as in the case of the larches and a few others, they carry their leaves throughout the winter, and the wood is usually softer than that of the broadleaf trees.

In contrast to the evergreens or conifers, which bear their seed naked on the cone-scales, there are the hardwoods or broadleaf trees, in which the seed is enclosed in seed cases, pods, or nuts. These also have woody stems which put on growth in the form of an annual layer of wood on the outer edge of the sapwood, but the leaves are broad as a rule, and netted-veined. The leaves of this class of trees are deciduous, or dropping off in the fall of the year, with the exception of a few species as the madrona, myrtle, chinquapin, and some of the species of the western oaks.

All plants have both common and scientific names. The former are usually the result of common usage in the region in which the plant is found, which in times becomes standardized in both botanical and economic uses. Many species have a great variety of common names, especially those whose range covers a considerable area under widely varying conditions. An example of this diversity of names being the western yellow pine which is found in British Columbia southward through Washington, Oregon, Idaho, California down into the southwestern states. This species has been variously named by the lumber trade, typical names being western soft pine, Arizona white pine, California white pine, Idaho pine, bull pine, blackjack, and others. Other species in the west have this difference in names due either to some special characteristics of the wood or form of the tree, or to its geographic location.

Scientific names are always in Latin,

or some Latinized form of a common name or of some person instrumental in its discovery or its description as a new species. Only one scientific name is recognized for any one species, and this name is given according to the well-established procedure devised and perfected by the eminent Swedish botanist and naturalist, Linnaeus, in his book "Species Plantarum", published in 1753. According to this system botanists of all countries have a common ground for the naming of plants for their identification and classification, irrespective of the fact that the common names are not understood internationally because of the different languages. The basis of this system is that each distinct kind of a plant is termed a *species,* while a group of closely related species constitutes a *genus.* Each species name is composed of two parts, consisting of the specific name, defining the species, and the generic name, denoting the genus, or the family. The specific name follows the generic name; furthermore in botanical works an abbreviation of the name of the botanist or person who first described the plant is appended. Thus the scientific name of western yellow pine is listed as *Pinus ponderosa,* Laws., this species being first described by Lawson.



Key to the Western Conifers

THERE are two principal classes of trees with which the forester and lumberman are concerned from a commercial standpoint. These are the so-called softwoods, also called the conifers or evergreens, botanically named the *Gymnospermae,* and the hardwoods, also known as the broadleafs, which are one of the two divisions of the main class of trees which are given the name of *Angiospermae.* The other division of this latter class consists of the palms, which are of no practical importance from a commercial forestry standpoint.

The conifers, or Gymnosperms, are further subdivided into two families, the *Coniferae* (cone-bearers) and *Taxaceae* (Yew-like.) The hardwoods, given the name of Dicotyledons (so-called because the germinating seeds produce two seed-leaves, or cotyledons) are subdivided into a large number of families, such as the willows, walnuts, maples, ashes, oaks, etc., which contain many species of great commercial importance in the eastern portions of the United States, but very few of importance in the west.

The principal distinction between the conifers and the broadleafs is that the coniferous species (of which the pines, firs, larches, spruces, and cedars are typical) have needle-shaped or scale-like leaves, usually persistent (except larch), either in clusters or singly, and bear seed in a wood-like cone; the leaves of the hardwoods are usually broad (not needle-like or scale-like) which usually drop off at the end of each growing season, while the seed is borne openly or in a nut or acorn or pod. The wood of the confiers is classed as resinous, that of the hardwoods is mostly non-resionous. The presence of resin ducts in the wood of the conifers distinguishes it at once from that of the hardwoods, where resin ducts are lacking.

KEY

A. Leaves needle-shaped or scale-like, usually persistent for one or more seasons (except larch); fruit a woody cone (except in juniper and yew where it is berry-like). *Gymnosperms* (CONIFERS AND YEW).

B. Leaves broad, not needle-shaped nor scale-like; fruit not a cone. *Angiosperms* (HARDWOODS).

CONIFERS AND YEW (Evergreens)

KEY TO GENERA

A. Leaves needle-shaped.

I. Leaves in bundles (not singly) on short side branchlets.

a. Needles 1 to 5 in a bundle, persistent; fruit matures in two seasons (three seasons in Torrey pine).

1. *Pinus.* PINES.

b. Needles 12 to 40 in a bundle, deciduous; fruit matures in one season.

2. *Larix.* LARCHES.

II. Leaves not in bundles, but scattered singly over the twigs; fruit matures in one season.

a. Leaves raised on small prominent cushions, which remain on the twigs after the leaves fall and cause the twigs to be roughened.

1. Leaves stiff, sharp-pointed, 3 or 4-angled.

3. *Picea.* SPRUCES.

2. Leaves soft, rounded at tip, flat.

4. *Tsuga.* HEMLOCKS.

b. Leaves not raised on cushions; leaf-scars sometimes slightly raised on edge opposite to tip of twig, flat and round.

1. Leaf-scars small, not depressed into bark, leaves not prominently twisted upward, flat; and soft; cones hanging.

5. *Pseudotsuga.* DOUGLAS FIRS.

2. Leaf-scars large and depressed into surface of bark; leaves decidedly curved and sometimes twisted at bases, flat or 4-sided, pointed or notched, stiff; cones erect, falling apart when ripe.

6. *Abies.* BALSAM FIRS.

c. Leaves attached by means of broad bases which run down the twigs.

1. Leaves without a stalk-like construction where they join the stems; fruit a woody cone maturing in one season.

7. *Sequoia sempervirens.* REDWOOD.

2. Leaves with a stalk-like construction; fruit a coral-red berry.

13. *Taxus brevifolia.* PACIFIC YEW.

B. Leaves not needle-shaped, but scale-like and closely appressed against the twigs, or awl-shaped.

I. Branchlets flat or flattened.

a. Cones longer than broad, maturing in one season; cone-scales thin.

1. Cone-scales 6 or less; leaves with long bases (¼ to ⅝ inches) not meeting from opposite sides, or only at the extreme base.

8. *Libocedrus decurrens.* INCENSE CEDAR.

2. Cone-scales more than 6; leaf-bases short (⅛ to 3/16 inches) meeting from opposite sides in a mere point.

9. *Thuya plicata.* WESTERN RED CEDAR.

b. Cones globular, ¼ to ½ inches in diameter, maturing in two seasons; cone-scales umbrella-shaped, meeting from opposite sides in a short line.

10. *Chamaecyparis.* CEDARS.

II. Branchlets not flat, but square or round.

a. Fruit a woody cone, sub-globose, maturing in 2 seasons, ½ to 1½ inches in diameter; seeds numerous under each scale.

11. *Cupressus.* CYPRESSES.

b. Fruit a bluish or red-brown berry-like cone, ¼ to ½-inch in diameter; leaves usually closely appressed to branches (awl-like and spreading in *J. communis*) arranged on all sides of twigs.
12. *Juniperus.* JUNIPERS.

c. Fruit a woody cone, ovoid, 1 to 2 inches long, maturing in 2 seasons; leaves awl-shaped, spreading, sharply pointed on the stouter stems, shorter and more appressed toward the tips.
7. *Sequoia washingtoniana.* BIGTREE.

KEY TO THE SPECIES OF CONFERS

1. Pinus. The Pines.

A. Leaves 5 in a bundle.

I. Cones long-stalked.

a. Cones elongated, bright green to light yellow-brown at maturity; cone-scales thin and without prickers; leaves soft, 2 to 4 inches long.

1. Cones 5 to 11 inches long; leaves deep green, rather appressed against the younger twigs and branchlets, leaves persistent for 3 or more seasons; bark is grayish to dark gray and broken into small coarse squares.
1. *P. monticola.* WESTERN WHITE PINE.

2. Cones 12 to 22 inches long; leaves yellow-green standing out almost at right angles from the twigs and branchlets, rarely persistent for more than 2 seasons; bark a deep reddish-brown or cinnamon-red color, with long irregular ridges.
2. *P. lambertiana.* SUGAR PINE.

b. Cones broad ovoid, 4 to 6 inches long, deep chestnut brown at maturity with thick scales armed with minute prickles; seeds oval, ¾ to one inch long with a thick hard shell; leaves 8 to 14 inches long.
3. *P. torreyana.* TORREY PINE.

II. Cones short-stalked, green or purple at maturity, scales thick; leaves 2 inches or less.

a. Cones 3 to 10 inches long, scales opening at maturity; seeds with wings.
4. *P. flexilis.* LIMBER PINE.

b. Cones 1 to 3 inches long, cone-scales remaining closed when ripe; seeds wingless.
5. *P. albicaulis.* WHITE-BARK PINE.

c. Cones ovoid-oblong, scales with prickers; leaves in crowded clusters, incurved, less than 2 inches long.

1. Cones 3½ to 5 inches long, armed with stunted incurved prickles.
6. *P. balfouriana.* FOXTAIL PINE.

2. Cones 2½ to 3½ inches long, armed with long slender prickles.
7. *P. aristata.* BRISTLECONE PINE.

B. Leaves in 1 to 5-leaved clusters; cones globose, 1 to 2 inches, green at maturity turning later to light brown; scales few, much thickened and concave; seeds large and edible; leaves 2 inches or less.

I. Leaves 2 or 3 in clusters, 1 to 2 inches long, dark-green; seeds ½ to ¾-inch long.
8. *P. cembroides.* MEXICAN PINYON.

II. Leaves usually in 4-leaved clusters, 1¼ to 1½ inches long, pale glaucus green.
9. *P. parryana.* PARRY PINE.

III. Leaves 2, rarely 3, in a bundle, stout, triangular, dark green, ¾ to 1½ inches long.
10. *P. edulis.* PINYON PINE.

IV. Leaves singly or in 2-leaved clusters, rigid, pale glaucus green, 1½ inches long.
11. *P. monophylla.* SINGLELEAF PINE.

C. Leaves 3 in a bundle; cones with short stalks.
  I. Cones symmetrical, ellipsoidal in shape with slender prickles, purple when ripe.
    a. Cones 3 to 6 inches long ; leaves yellow-green, 5 to 11 inches long.
      12. *P. ponderosa.* WESTERN YELLOW PINE.
    b. Cones 6 to 12 inches long; leaves dark bluish-green, 5 to 11 inches long.
      13. *P. jeffreyi.* JEFFREY PINE.
  II. Cones lop-sided.
    a. Cones 4 to 6 inches long, do not open when ripe; scales not prolonged into stout, straight or curved spines; leaves 4 to 6 inches long.
      1. Cones ovoid or pointed; prickles of cone-scales minute; leaves deep grass-green.
        14. *P. radiata.* MONTEREY PINE.
      2. Cones elongated and rounded at tip; prickles of cone-scales stout; leaves yellow to blue-green.
        15. *P. attenuata.* KNOBCONE PINE.
    b. Cones 6 to 14 inches long, opening when ripe; scales prolonged into stout straight or curved prickles; leaves stout, 7 to 12 inches long.
      1. Cones oblong-ovoid, 6 to 10 inches long; seeds longer than the wings; foliage in crowns open, pale blue-green color.
        16. *P. sabiniana.* DIGGER PINE.
      2. Cones oblong-conic, 9 to 14 inches long; seeds shorter than the wings; foliage in crowns dense, dark blue-green color.
        17. *P. coulteri.* COULTER PINE.

D. Leaves 2 in a bundle.
  I. Leaves 1 to 3 inches long; cones lop-sided, 1½ to 2½ inches long armed with slender prickles; cones persistent and remain closed on tree for long period.
    18. *P. contorta.* LODGEPOLE PINE.
  II. Leaves 4 to 6 inches long; cones lop-sided, 2 to 3½ inches long, armed with stout prickles; cones persistent and remain closed on tree.
    19. *P. muricata.* BISHOP PINE.

2. Larix. The Larches.

A. Leaves flat to triangular, 14 to 30 in a cluster, 1 to 1¾ inches long; branchlets thinly covered with hair; cones oblong, 1 to 1½ inches long.
  1. *L. occidentalis.* WESTERN LARCH.

B. Leaves more or less 4-angled, 30 to 40 in a cluster, 1 to 1½ inches long; branchlets thickly covered with fine woolly substance; cones ovoid, 1½ to 2 inches long.
  2. *L. lyallii.* ALPINE LARCH.

3. Picea. The Spruces.

A. Leaves distinctly 4-angled, blue-green; cone-scales truncate or acute at apex.
  I. Leaves soft and flexible; branchlets covered with very fine hair; cones 1 to 3 inches long, usually 2 inches.
    1. *P. engelmannii.* ENGELMANN SPRUCE.
  II. Leaves rigid and sharp to the touch; branchlets without hairy covering; cones usually 3 inches long.
    2. *P. pungens.* BLUE SPRUCE.

B. Leaves flat or only indistinctly 4-angled; cone-scales rounded.
  I. Branchlets without hair; leaves rigid, sharp to the touch and standing out at nearly right angles from all sides of the branches; cones 2½ to 4 inches long, oblong-cylindric in shape, yellow-green; cone-scales feathery and stiff with corrugations at the tips.
    3. *P. sitchensis.* SITKA SPRUCE.
  II. Branchlets hairy; cones purplish-green, ellipsoidal, 2 to 4 inches long; cone-scales not corrugated.
    4. *P. breweriana.* WEEPING SPRUCE.

4. Tsuga. The Hemlocks.

A. Leaves decidedly flat, distinclty 2-ranked, rounded at apex and conspicuously grooved; cones oblong-ovoid, ¾ to 1-inch long; bracts bluntly pointed.
1. *T. heterophylla.* WESTERN HEMLOCK.

B. Leaves plump, from all sides of branches with appearance of being in clusters; cones oblong-cylindric, 1 to 3 inches long; bracts sharply pointed.
2. *T. mertensiana.* MOUNTAIN HEMLOCK.

5. Pseudotsuga. The Douglas Firs.

A. Leaves usually rounded or bluntly pointed at tips, dark yellow-green or sometimes blue-green; cones 2½ to 4 inches long, their bracts extending considerably beyond the cone-scales.
1. *P. taxifolia.* DOUGLAS FIR.

B. Leaves bluntly to sharply pointed, bluish-gray; cones 4 to 6½ inches long, their bracts extending only slightly beyond the cone-scales.
2. *P. macrocarpa.* BIGCONE FIR.

6. Abies. The Balsam Firs.

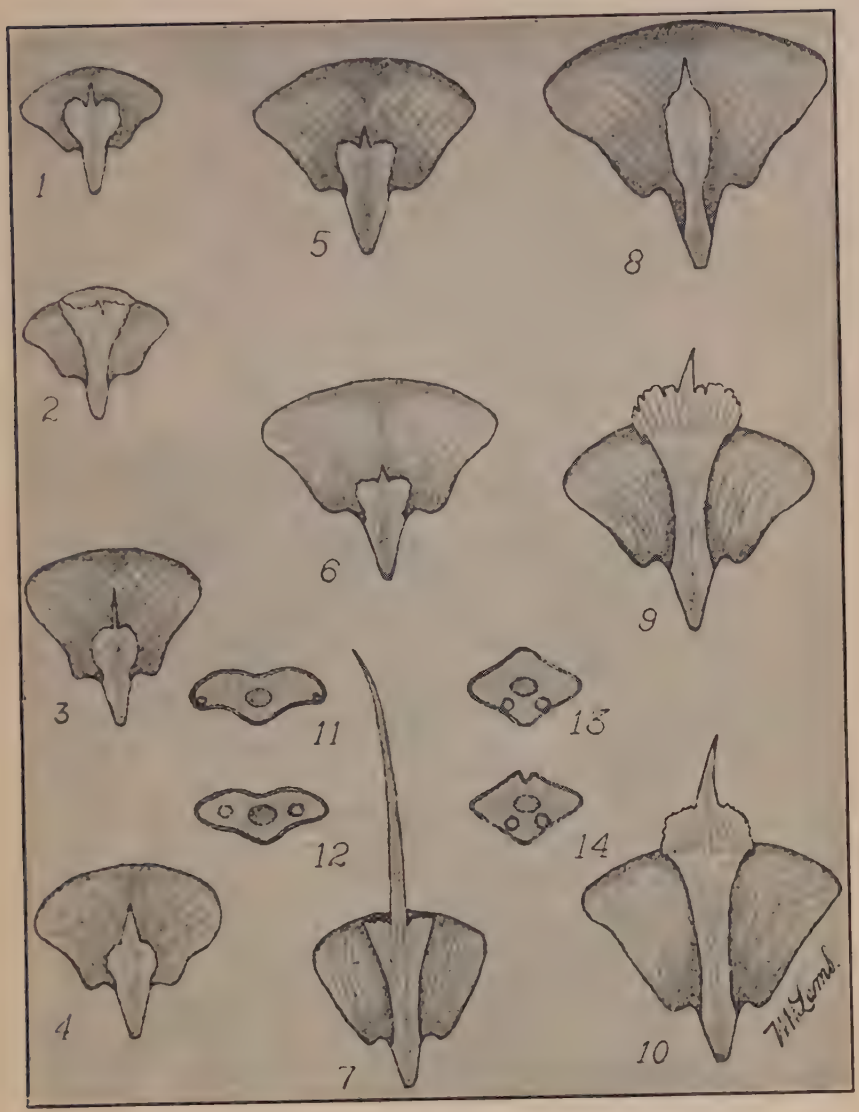
A. Leaves flattened.
I. Leaves with stomata on upper and lower surfaces.
a. Leaves without pronounced twist at the bases, 1 to 1¾ inches long; resin ducts large, up in pulp of leaf; cones 3 to 4 inches long, sometimes 5 inches, dark purple; cone-scales usually longer than broad; bracts shorter than cone-scales with abruptly rounded shoulders and long tapering points.
1. *A. lasiocarpa.* ALPINE FIR.

b. Leaves with decided twist at the bases, 1½ to 2½ inches long, distinctly 2-ranked; resin ducts small, close to lower margin of leaf; cones 3 to 5 inches, green, dark purple or yellow, bracts shorter than cone-scales with either rounded or squared shoulders, with short abruptly pointed tips.
2. *A. concolor.* WHITE FIR.

II. Leaves with stomata on lower surfaces only, none on upper side of leaves.
a. Leaves with decided twist at bases, deep green color on upper surface, silvery white underneath; resin ducts small, close to lower margin.
1. Leaves appearing as if growing from both sides and top of twigs, ¾ to 1¼ inches long; cones 3½ to 6 inches long, oblong; bracts shorter than cone-scales, with long thickened points.
3. *A. amabilis.* SILVER FIR.
2. Leaves presenting distinclty 2-ranked appearance, 1 to 1¾ inches long; cones 2 to 4 inches long, green, dark purple, or yellow; bracts shorter than cone-scales, with either rounded or squared shoulders with short abruptly-pointed tips.
4. *A. grandis.* LOWLAND WHITE FIR.
3. Leaves distinctly 2-ranked, 1½ to 2½ inches long, sharptly pointed; cones 2¾ to 3½ inches long, purplish-brown, oval, with long, slender needle-like bracts protruding from among the cone-scales.
5. *A. venusta.* BRISTLECONE FIR.

B. Leaves thickened, more or less 4-angled, with stomata on all surfaces, not stalked; resin ducts near lower surface of leaves, but remote from margins.
I. Leaves with groove in upper surfaces, slightly ridged below, 1 to 1¼ inches long on lower crown and ⅝ to ¾-inch long on upper crown, bluntly to sharply pointed; cones 4½ inches to 7 inches long, cylindrical, over twice as long as broad; bracts completely covering the exterior of the cone, with very long tapering points.
6. *A. nobilis.* NOBLE FIR.

II. Leaves without groove in upper surfaces, ¾ to 1½ inches long, bluntly pointed.
a. Cones 6 to 9 inches long, oblong-cylindric in shape, dark purple-



A CONSPECTUS OF NORTH AMERICAN BALSAM FIRS

Cone-scale and bract, natural size: (1) *Abies balsamea*, (2) *A. fraseri*, (3) *A. lasiocarpa*, (4) *A. amabilis*, (5) *A. grandis*, (6) *A. concolor*, (7) *A. venusta*, (8) *A. magnifica*, (9) *A. shastensis*, (10) *A. nobilis*.

Cross-section of leaf, enlarged: (11) Resin ducts near lower surface of leaf, *A. concolor* and *A. grandis*, (12) Resin ducts up in pulp of leaf, *A. lasiocarpa*, (13) *A. magnifica* and *shastensis*, (14) *A. nobilis*.

(1) and (2) are eastern species.

—Reprdouced from Journal of Forestry.

brown; bracts shorter than cone-scales, gradually narrowing into short, stout points.

7. *A. magnifica.* CALIFORNIA RED FIR.

b. Cones 4 to 6 inches long, somewhat ovoid in shape, less than twice as long as broad; some of the bracts extruding beyond cone-scales with mediumly long points, and commonly covering outside of cone only incompletely.

8. *A. magnifica shastensis.* SHASTA RED FIR.

10. Chamaecyparis. The Cedars.

A. Bark thin, usually ¼ to ⅜-inch; branchlets stout; leaves feel prickly to the touch, dark blue-green color; cones about ⅜ to ½-inch in diameter.

2. *C. nootkatensis.* ALASKA CEDAR.

B. Bark thick, 2 to 8 or 10 inches; branchlets slender, leaves bright green, conspicuously glandular; cones about ¼ to ⅜-inch in diameter.

2. *C. lawsoniana.* PORT ORFORD CEDAR.

11. Cupressus. The Cypresses.

A. Leaves dark green.

I. Leaves without glands.

a. Leaves bluntly pointed; cones 1 to 1½ inches in diameter with 8 to 12 scales; seeds light chestnut-brown.

1. *C. macrocarpa.* MONTEREY CYPRESS.

b. Leaves sharply pointed; cones ½ to ⅝-inch in diameter with 6 to 10 scales; seeds dark brown or black.

2. *C. goveniana.* GOWEN CYPRESS.

II. Leaves glandular-pitted on the back, sharply pointed.

a. Cones ¾ to 1-inch in diameter, sub-globose; 6 to 8 scales; seeds brown.

3. *C. sargentii.* SARGENT CYPRESS.

b. Cones ½ to 1-inch in diameter, oblong, often covered with whitened bloom; usually 6 scales; seeds dark chestnut brown.

4. *C. macnabiana.* MACNAB CYPRESS.

12. Juniperus. The Junipers.

A. Leaves needle-like, awl-shaped, sharp pointed, chalky-white on one side; fruit bright-blue, mealy and resinous, about ¼-inch in diameter.

1. *J. communis.* DWARF JUNIPER.

B. Leaves mostly flat or scale-like, closely appressed, free and awl-shaped on vigorous shoots and young plants.

I. Fruit red or reddish-brown.

a. Leaves alternate (rarely opposite); fruit short-oblong; ¼ to ½-inch in diameter.

2. *J. californica.* CALIFORNIA JUNIPER.

b. Leaves opposite (rarely alternate); fruit sub-globose, ¼ to ⅓-inch in diameter (a variety *megalancocarpa* has a fruit ¾-inch in diameter).

3. *J. utahensis.* UTAH JUNIPER.

II. Fruit blue or blue-black.

a. Leaves opposite or alternate, toothed; fruit matures in one season.

1. Branchlets about 1/10-inch in diameter; leaves acute; fruit ¼ to ⅓-inch in diameter; seeds 2 or 3.

4. *J. occidentalis.* WESTERN JUNIPER.

2. Branchlets not over 1/20-inch in diameter; leaves usually alternate, sharply to bluntly pointed; fruit ⅛ to ¼-inch in diameter; seeds 1, or rarely 2.

5. *J. monosperma.* ONE-SEEDED JUNIPER.

b. Leaves mostly opposite, bluntly to sharply pointed, naked on the margins; fruit ripening at end of second season, ¼ to ⅓-inch in diameter; 1 or 2 seeds.

6. *J. scopulorum.* ROCKY MOUNTAIN JUNIPER.

The Western Forest Regions

THE commercial forests of the western United States may be broadly subdivided into five principal zones, or forest areas. These are (1) the *Pacific Coast* forest zone, taking in the more humid portions of western Washington, western Oregon, and northwestern California; (2) the *Intermountain,* or western yellow pine zone, which includes the drier regions of the central and eastern portions of Washington and Oregon, southern Idaho, northern California, Nevada, and the Rocky Mountains of Utah, Colorado, Arizona, and New Mexico; (3) the *Northern Rocky Mountains* zone of northeastern Washington, northern Idaho, and western Montana; (4) the *Upper Slope Cascade-Sierra* zone in Washington, Oregon and California; and (5) the *Upper Slope Rocky Mountain* zone from the Canadian boundary south to Arizona and New Nexico.

The Pacific Coast Forest Zone

The outstanding forest zone in the United States, and perhaps anywhere in the world, is that of the western portions of the Pacific Coast states of Washington, Oregon, and northwestern California. This rather narrow belt of timber, some 1,000 miles in length and from 30 to 150 miles in width, is the habitat of the largest commercial trees in the United States. These are the redwoods, *Sequoia sempervirens;* Douglas fir, *Pseudotsuga taxifolia;* Sitka spruce, *Picea stichensis;* western red cedar, *Thuya plicata,* and western hemlock, *Tsuga heterophylla;* trees that attain average sizes at maturity of from 4 to 7 or 8 feet in diameter and from 200 to 275 feet in height. Exceptional trees of redwood are 18 or 20 feet in diameter and 300 to 330 feet in height; Douglas fir, Sitka spruce and western red cedar have been found up to 14 to 16 feet in diameter, while Douglas fir trees have been found up to 325 feet in height. Other species common to this zone, and attaining diameters of from 4 to 6 feet and from 175 to 225 feet in height are lowland white fir, *Abies grandis;* Port Orford cedar, *Chamaecyparis lawsoniana;* silver fir, *Abies amabilis,* and noble fir, *Abies nobilis.*

The Pacific Coast forests are favored with exceptionally mild climatic conditions, excessive humidity, comparatively low altitudes, and fairly good soil conditions for forest growth. All of these factors tend toward rapid tree growth, and nowhere else in the United States are all of these favorable conditions met with to such an extent as here.

This forest zone may be subdivided into two general forest regions, or broad forest types—the Douglas fir region of western Washington and western Oregon, and the redwood region of northwestern California and southwestern Oregon. In both these broad forest types other species occur, but the distinctive species in the first is Douglas fir, and in the second is redwood, and the general regions are called after the predominating species in each.

The Douglas Fir Region

This region comprises the western portions of Washington and Oregon, and extends northward into the southwestern portion of British Columbia. It is generally below 3,000 or 3,500 feet in elevation in Washington, and below 4,000 to 4,500 feet in Oregon, and extends from the western slopes of the Cascade Range to the shores of the Pacific Ocean. Douglas fir forms the principal species in point of

MATURE FOREST OF DOUGLAS FIR

quantity, size, quality of the wood for general purposes, and in the amount manufactured. It occurs principally in pure or almost pure stands, usually occupying 75 per cent or more of the volume. It is the predominant tree in this region, and no doubt will be for all time to come under scientific forestry practice in the future.

Associating with Douglas fir in mixture, and sometimes occuring over considerable areas in pure stands, are other highly desirable commercial species: Sitka spruce, western red cedar, Port Orford cedar, western hemlock, noble fir; other species now not so valuable for lumber, but especially desirable for pulp, are silver fir and lowland white fir.

The dominant species in this region are the conifers, only a very inconsiderable portion of the area being occupied by hardwoods, or the broadleaf trees. These are usually only along the river bottoms and moister situations at the lower elevations. The principal hardwoods are red alder, *Alnus rubra;* black cottonwood, *Populus trichocarpa;* bigleaf maple, *Acer macrophyllum;* Oregon white oak, *Quercus garryana;* California black oak, *Q. californica;* Oregon ash, *Fraxinus oregona;* tanoak, *Lithocarpus densiflora.* Of the above hardwoods only red alder, black cottonwood, and bigleaf maple have been used to any extent for commercial purposes outside of fuelwood or fence post material. Oregon myrtle, *Umbellularia californica,* is in demand as a specialty wood for novelties and special panel work, while the bark of tanoak has been used for tanning purposes to a great extent.

The Redwood Region

The redwood region, in which redwood is the predominant species, occupies a comparatively narrow strip, from 30 to 50 miles in width, bordering on the shores of the Pacific Ocean, and extending from Monterey County, California, north into southwestern Oregon to about 20 miles north of the California - Oregon boundary. Its commercial range is limited to that portion north of San Francisco Bay and to a strip usually not over 20 to 25 miles in width.

Redwood forms the predominating tree in this region, although as a forest type it plays a relatively small part. The greater portion of the redwood region is composed of a mixture of redwood (from 50 to 75 per cent), Douglas fir, lowland white fir, western hemlock, western red cedar, tanoak and madrona. Other forest types occurring are usually mixtures of various species composed of a small proportion of redwood, Sitka spruce, Port Orford cedar, western hemlock, and lowland white fir upon the rich river flats of the lower elevations.

The Intermountain Forest Zone

The Intermountain forest zone covers an extensive region, consisting of an area made up of principally western yellow pine, *Pinus ponderosa* (also called pondosa pine), extending from the interior of southern British Columbia, between the Cascade Range and Sierra Nevada on the west and the Rocky Mountains on the east, southward to Arizona and New Mexico. Spurs of western yellow pine timber are also found extending eastward in the Black Hills in South Dakota. The timbered portions of this zone are concentrated into a number of distinct forest units, which are separated by non-timbered areas of desert land, agricultural and grazing lands, and mountainous areas.

The principal timbered regions in this zone are (1) the northern pine forests of southern British Columbia,

eastern Washington, eastern Oregon, Idaho, and California; (2) the southwestern pine forests in the southern Rocky Mountains and San Francisco Mountains in Utah, Colorado, New Mexico, and Arizona.

This forest zone occurs in a region principally with relatively low precipitation and of low humidity, resulting in semi-arid conditions over great portions of it. Exceptions to these extreme drouth conditions are found in the sugar pine-western yellow pine region in the western Sierra Nevada and Coast Range in California, where, due to the proximity of the Pacific Ocean and the western exposures, more favorable climatic conditions are found. As a rule the forests in this zone are at rather high elevations; from about 3,000 feet to 6,000 feet in the northern pine region, and from 7,000 feet to 10,000 or 11,000 feet in the southwest.

The Northern Yellow Pine Region

In the northern yellow pine region the western yellow pine type is of the greatest importance, while further south, in northern California and portions of southern Oregon, the sugar pine-yellow pine type predominates. Other forest types which cover considerable areas are the mixed white fir-Douglas fir-larch type, the pure lodgepole pine type, the larch-Douglas fir type, and the pure white fir type.

In the western yellow pine type, which covers extensive areas in eastern Oregon, eastern Washington, southern Idaho, and northeastern California, western yellow pine, *Pinus ponderosa,* is the principal species. In the lumber trade in this region this tree and its products are known as "pondosa pine". As a rule this forest type has few other species in mixture with the yellow pine, and this to only a very slight extent. These other species are Douglas fir, lowland white fir, western larch, *Larix occidentalis;* lodgepole pine, *Pinus contorta;* western white pine, *Pinus monticola,* and sugar pine, *Pinus lambertiana.*

The sugar-yellow pine type in California and southern Oregon is a forest type of great commercial importance. The principal species are sugar pine and western yellow pine. Other species found are Jeffrey pine, *Pinus jeffreyi;* red fir, *Abies magnifica;* white fir, *Abies concolor;* Douglas fir, Shasta red fir, *Abies magnifica shastensis,* and incense cedar, *Libocedrus decurrens.* This forest type produces the maximum sizes of pine timber found anywhere in the United States.

Other forest types found in the northern yellow pine region are of comparatively small extent and of lesser commercial value at the present time. The white fir-Douglas fir-larch type is usually found upon the moister situations, such as the slopes and benches having slightly greater rainfall and a greater moisture content in the soil. Other species occurring in this type are western yellow pine, western white pine, and lodgepole pine. In stands such as this the few scattering yellow and white pines found in this type attain their maximum growth and sizes. The lodgepole type, which occupies considerable area in this region, is of little commercial importance, although no doubt in the future, where trees attain commercial sizes, this type will be held in better appreciation. It is now of great value in preserving forest cover conditions over large areas which otherwise would be desert land of no value. Lodgepole pine is the principal tree; other species found are western yellow pine, western larch, Douglas fir, and white fir principally. Of considerable extent is portions of this region upon the moister

slopes, is found the balsam type, consisting in some places of pure stands of white fir, while in other places a mixed stand of the balsams with Douglas fir and yellow pine. These are of low commercial value at the present time, although of great potential value in the future both from the standpoint of lumber manufacture and for the manufacture of pulp and paper.

The Southwestern Yellow Pine Region

Covering a considerably greater area than the northern yellow pine region, the southwestern yellow pine forests occur at rather high elevations on the plateaus of Utah, Colorado, New Mexico, and Arizona. The western yellow pine type is the principal forest type in this region, western yellow pine being the most valuable species, and occurring in practically pure stands. Of lesser commercial importance, but of great value in keeping land under forest conditions is the pinon-juniper type, occurring usually upon the slopes at elevations below the western yellow pine type. In this region the yellow pine is usually smaller and in less dense stands than it occurs in the northern pine region. This is mainly because of the more adverse climatic conditions due to lack of sufficient rainfall.

Northern Rocky Mountain Zone

The Northern Rocky Mountain timber zone is found in the more humid regions of northern Idaho and western Montana. There are three principal forest types found here—the western white pine type, the mixed larch-Douglas fir type, and the lodgepole pine type.

The western white pine forest type is of the greatest commercial importance, and it occurs principally in northern Idaho, and adjacent portions of northeastern Washington and western Montana. The predominant species is western white pine, *Pinus monticola;* other species are western red cedar, western hemlock, lowland white fir, Douglas fir, western larch, and lodgepole pine. The principal lumbering operations in this region are now taking place in the western white pine forests. This forest type is generally found at from 2,000 to 5,000 feet above sea-level upon the better well-drained soils in the most humid parts of Idaho and Montana. It forms a very important forest belt in the mountainous region west of the Bitterroot divide between the lower yellow pine and sub-alpine forests.

The western larch-Douglas fir type is usually a mixed forest type in which these two species form the predominant proportion. It covers considerable areas in western Montana, and a lesser area in northern Idaho. Larch is usually the principal tree in this type, forming more than 50 per cent of the stand as a rule. Other species found are lodgepole pine, lowland white fir, western hemlock, Engelmann spruce, and western white pine. The altitudinal range of the larch-Douglas fir type is mainly from 2,000 to 5,000 feet, preferring the moister slopes and benches with north and west exposures. It occupies an intermediate position between the yellow pine and the subalpine (balsam) types wherever it is found.

The lodgepole pine type is found over considerable portions of central Idaho, western Montana, and northwestern Wyoming. Its commercial altitudinal range in Idaho is from 2,000 to 3,000 feet; in Montana at from 6,000 to 8,500 feet. Lodgepole pine is the principal species in this type. Other species found are lowland white fir, western larch, Douglas fir, Englemann spruce, and alpine fir. This

type is of geat commercial importance in western Montana, where large quantities of lodgepole pine are used in the mining industry in that state.

Upper Slope Cascade-Sierra Zone

This forest zone comprises two rather distinct forest mixtures which are typical of the higher elevations on both sides of the Cascade Range and the Sierra Nevada, namely, (a) the balsam-mountain hemlock mixture of Washington and northern Oregon; and (b) the balsam-Douglas fir mixture of southern Oregon and northern California.

The balsam-mountain hemlock type is found along the higher slopes of the Cascade Range at elevations usually above 3,000-3,500 feet in Washington, and from 4,000 to 6,000 feet in Oregon. In Washington the principal species are usually silver fir, alpine fir, *Abies lasiocarpa;* mountain hemlock, *Tsuga mertensiana,* and Alaska cedar, *Chamaecyparis nootkatensis,* upon the western slopes; and silver fir, lowland white fir, alpine fir, alpine larch, *Larix lyalli;* mountain hemlock, Englemann spruce, and Alaska cedar upon the eastern slopes. In the southern parts of this zone, in Washington and northern Oregon, extending southward to the south Santiam watershed, noble fir forms a considerable portion of the stand, with Alaska cedar and alpine larch either dropping out altogether or occurring only in limited quantities.

Further south in the Cascades and Sierras, in southern Oregon and northern California, the predominant species in this zone are lowland white fir, white fir, Shasta red fir, *Abies magnifica shastensis;* red fir, *Abies magnifica;* alpine fir, mountain hemlock, Douglas fir, and incense cedar, with a scattering of western yellow pine, Jeffrey pine and western white pine.

At the present time these upper slope forests are of little commercial value, because of the extensive stands of Douglas fir, western yellow pine, redwood, and other species at more easily reached lower elevations; however, with the cutting out of these more accessible stands lumbering operations will be forced more and more upon the upper slopes, and the time will come when the upper slope forests will be recognized as desirable for use either in the manufacture of lumber, boxes, general and specialty products, and pulp and paper, etc.

Upper Slope Rocky Mountain Zone

The upper slope zone in the Rocky Mountains extends along the higher elevations in this mountain range from the Canadian boundary southward to Arizona and New Mexico. It is essentially a balsam-spruce forest mixture, consisting principally of lowland white fir, alpine fir, and Englemann spruce in Idaho and Montana; and white fir, alpine fir, Engelmann spruce, and blue spruce in Wyoming, Utah, Colorado, Arizona, and New Mexico. Other species occurring in this zone at the northern portions are mountain hemlock, lodgepole pine, alpine larch, limber pine, *Pinus flexilis;* western white pine, western larch, and Douglas fir; in the southern portions of the zone the other species found are Douglas fir, lodgepole pine, and limber pine.

This balsam-spruce type of the Rockies is found at from 3,000 to 6,000 feet elevation in Idaho and Montana, and from 6,000 to 10,000 feet in the southern Rocky Mountain states. The principal commercial tree of this zone is Engelmann spruce; however, all the other species are of good quality and will be more in demand as the present stands of high quality and more easily reached western white pine and western yellow pine in this region are cut out.

Forest Statistics

THE total forest area in the United States in 1925 was estimated at 500 million acres, of which 80 million acres were covered with only cordwood and small growth, leaving 470 million acres as commercial saw timber. In addition the territory of Alaska contains some 95 million acres of forest land. Of the 470 million acres of saw timber, we have the following segregation according to regions and classes of ownership:

FOREST AREAS BY REGIONS AND OWNERSHIP, 1925
(In millions of acres)

Region	Total Forest Area	Federal		State	Private	
		Total	National Forest	County City	Total	Farms and Woodlots
Pacific Coast	59.6	32.3	28.8	1.6	25.7	7.0
Rocky Mountain	60.3	51.2	47.8	2.0	7.1	3.5
East and South.....	349.6	5.6	4.6	7.6	336.4	116.5
Totals	469.5	89.1	81.2	11.2	369.2	127.0

Pacific Coast region includes Washington, Oregon, California, and Nevada.

Rocky Mountain region includes Colorado, Wyoming, Utah, New Mexico, Arizona, Idaho, and Montana.

COMMERCIAL FOREST AREA AND TIMBER STAND WESTERN STATES, JANUARY 1, 1928

PACIFIC COAST REGION

State	Commercial Forest Area, Acres	Commercial Timber Stand Billion Board Feet
Washington	11,541,000	256.6
Oregon	23,035,000	375.0
California and Nevada.....	18,310,000	274.0
Totals	52,886,000	905.6

ROCKY MOUNTAIN REGION

State	Commercial Forest Area, Acres	Commercial Timber Stand Billion Board Feet
Idaho	12,850,000	77.8
Montana	13,200,000	48.8
Arizona	5,300,000	20.5
Colorado	8,650,000	25.0
New Mexico	5,500,000	17.0
Utah	3,550,000	15.0
Wyoming	5,700,000	20.0
Totals	54,750,000	224.1

The western forest regions contain an estimated stand of 1,132 billion board feet of sawtimber, or approximately one-half of the remaining timber stand in the United States. Of this stand the Pacific Coast states contain slightly more than 900 billion board feet, while the Rocky Mountain states have 227 billion board feet. In addition to the commercial sawtimber there are also estimated to be about 210 million cords of small timber suitable only for firewood, posts, small poles, mining timbers, etc., in these two western forest regions.

SAWTIMBER STAND BY SPECIES IN WESTERN UNITED STATES
(In billion board feet)

1928

Species	Rocky Mountain States	Pacific Coast States	Total
Douglas Fir	35.5	382.0	417.5
Western Yellow and Jeffrey Pine	60.0	155.3	215.3
Western Hemlock	1.1	77.0	78.1
Western Larch	23.0	7.5	30.5
Balsam Firs	8.4	82.5	90.9
Redwood	.....	69.0	69.0
Western White and Sugar Pine	15.0*	34.3†	49.3
Western Red Cedar	3.3	36.5	39.8
Lodgepole Pine	39.1	7.0	46.1
Spruce	26.3‡	11.0§	37.3
Incense Cedar	.....	9.1	9.1
Others	15.0	34.4	49.4
Totals	226.7	905.6	1,132.3

* Western white pine exclusively; † mostly sugar pine; ‡ Engelmann spruce; § mostly Sitka spruce.

The Western National Forests

OF GREAT importance in the west are the national forests, which are timber areas in the ownership of the federal government. These lands are being handled in such a manner as to maintain a constant source of timber for all time, and so that all of their resources be developed for the benefit of the Nation. Besides the timber values in the national forests, there are important grazing lands, recreation areas, summer home sites, power and irrigation sites, and other lands which are open to use under the regulations. These national forest lands are under the jurisdiction of the U. S. Department of Agriculture, and administered by the Forest Service, which is a branch of this department.

The main headquarters of the Forest Service are in Washington, District of Columbia, but for the most efficient administration of the national forest units eight district offices and one hundred forty-eight forest supervisors offices have been established. These district offices are the local headquarters of the eight regional forest districts, and the greater part of the actual administration as regards the broad policies to be followed in each district is handled there. These district headquarters are situated as follows:

Dist. No.	Headquarters	States Under Jurisdiction
I	Missoula Mont.	Montana, northeastern Washington, northern Idaho, northwestern South Dakota
II	Denver, Colo.	Colorado, Wyoming, South Dakota, Nebraska, Minnesota, Michigan, western Oklahoma
III	Albuquerque, N. M.	Arizona, New Mexico
IV	Ogden, Utah.	Utah, South Dakota, western Wyoming, Nevada, northwestern Arizona
V	San Francisco, Calif.	California, southwestern Nevada
VI	Portland, Ore.	Washington, Oregon
VII	Washington, D. C.	Alabama, Arkansas, Florida, Georgia, Kentucky, Maine, Maryland, New Hampshire, New Jersey, New York, North Carolina, Pennsylvania, Porto Rico, South Carolina, Tennessee, Virginia, West Virginia, eastern Oklahoma
VIII	Juneau, Alaska	Alaska

NET NATIONAL FOREST AREAS IN THE WESTERN STATES
(June 30, 1928)

State	N. F. Area in Acres	Sawtimber Million Board Feet	Small Timber Cords
Arizona	11,349,835	14,385	11,426,533
California	19,007,370	100,599	24,770,795
Colorado	13,278,233	22,167	5,694,479
Idaho	19,279,539	46,993	6,017,207
Montana	16,196,909	28,495	†.....
Nevada	4,979,019	268	6,612,756
New Mexico	8,515,117	11,187	13,448,059
Oregon	13,287,866	138,266	†.....
Utah	7,486,642	5,225	6,669,716
Washington	9,633,905	77,155	†.....
Wyoming	8,548,275	14,447	2,813,427
Totals	131,562,710	459,187	*77,452,972

† Figures not available. * Exclusive of Montana, Oregon, and Washington.

Generally the national forest areas consist of the more rugged and upper slopes of the mountainous regions of the western United States, and as a result large portions are absolutely bare of tree growth, or contain only a scattered stand of stunted trees which can not be classed as commercial timber. For example, out of the 13,287,866 acres of national forest land in Oregon, there are 5,458,867 acres which are classed as above timber line, consisting of high or rough and rocky areas containing scrubby, non-merchantable stands, brush lands, barren lands, rocky peaks, etc. In the same manner, only more so, out of the 9,633,905 acres in the state of Washington, over 7 million acres are placed in the bare land and non-merchantable timber class. This same situation applies in greater or less degree to all of the national forest lands throughout the western states. However, these latter areas serve the purpose of watershed protection, whereby a more constant flow of water is assurred for water power, irrigation, and domestic purposes.

The commercial forest lands within the national forests are handled with the primary object of assuring a continuous crop of timber for all time to come. Timber lands which are cut over are cut in such a manner that the desirable young growth is not destroyed, and that a crop of new trees will be obtained after cutting. Areas not reforesting, following forest fires, are planted with young trees grown in the forest nurseries provided for this purpose.

LOGGING IN DOUGLAS FIR REGION

Douglas Fir
(Pseudotsuga taxifolia)

DOUGLAS fir, formerly known as yellow fir, red fir, Oregon pine, and a variety of lesser known names, is the pre-eminent tree in the Pacific Northwest. As an individual tree and as a forest type, it covers a wide range, and forms about 60 per cent of the total standing timber in this region, consisting of the states of Washington, Oregon, northern California, Idaho and Montana. Individual specimens are found up to 325 feet tall and 10 to 15 feet in diameter, containing as high as 50,000 to 60,000 board feet.

In the lumber industry of the country, Douglas fir occupies a prominent position, forming about 20 per cent of the total lumber cut in the United States; in the Pacific Northwest it is the most important tree in this industry, here comprising about 60 per cent of the total lumber output.

Douglas fir was first reported in 1792 at Nootka Sound, Vancouver Island, by Archibald Menzies during the voyage of Captain Vancouver. It was the first species cut and exported from the Columbia river region by the Hudson's Bay trading post at Vancouver, Wash., at which time for the want of a better name, it was listed as "Oregon pine" in the ships declaration. Later it was named in honor of David Douglas, a Scottish botanist, who introduced it into Europe in 1827.

Douglas fir is not one of the balsam firs and it has no related species in this country; it resembles in some ways both the true firs (balsams) and the hemlock. Its scientific name, *Pseudotsuga,* is derived from the Greek word *"pseudo",* meaning false, and the Japanese word *"tsuga",* meaning hemlock; literally "false hemlock".

Range and Occurrence

Douglas fir is found in western North America from British Columbia southward, through Washington and Oregon to central California, northwestern Texas, southern New Mexico, Arizona, Utah, Colorado, and northern Mexico; and eastward in Idaho and Montana.

More specifically it occurs in two rather distinct forms, the Pacific coast and the Rocky mountain, differing mainly in its size and the quality of the wood. Commercially in the Pacific coast region, Douglas fir is found in western British Columbia, western Washington, and western Oregon, and to a lesser extent east of the Cascade range in these same states, western Idaho, and northwestern California.

As a forest type, it is found from sea level to about 4000 feet west of the Cascades, varying from about 2000 feet in British Columbia to almost 5000 feet in southern Oregon. East of the Cascades its range is from about 4000 to 6000 feet in altitude.

Chiefly, Douglas fir forms stands over large areas of nearly pure composition, although in the older mature forests there is almost always an admixture of western hemlock, red cedar, Sitka spruce, or silver fir, and to a lesser extent lowland white fir and noble fir. East of the Cascade range its principal associates are western larch, lodge pole pine, white fir and western yellow pine. For its best development Douglas fir prefers

DOUGLAS FIR *(Pseudotsuga taxifolia)*

a. Fruiting branch showing pendant cone with extruded bracts.
b. Detail and arrangement of leaves and winter buds.
c. Matured cone with reflexed scales.
d. Outside of cone scale showing the slender acutely lobed and extended bract bearing a spear-like point in the notch.
e. Winged seed showing two sides.
(*x* indicates scale of reduction)
—Photo Courtesy Oregon State Board of Forestry.

a fresh, well-drained, porous deep loamy soil, and generally avoiding saturated, poorly-drained situations. It is, however, adapted to a greater variety of soils, for with an abundance of atmospheric moisture the quality of the soil need not be so good.

In the Pacific Coast region, where the climate is humid and moderate, Douglas fir attains its best develop-

ment. Extremes in temperature are not found in this region, while there is an abundance of atmospheric moisture. Generally the annual rainfall varies from about 40 to over 100 inches, while the temperature rarely gets below about +25° F. throughout the greater part of its commercial range. In the region east of the Cascade Range and in the Rockies, the precipitation is much less, while ing a second crop of Douglas fir is to prevent fires from running over the cut-over areas, as each time fire goes over an area being restocked the young growth already started is destroyed and thus eventually all power of reproduction is done away with. In logging operations in Douglas fir stands, it is recommended that the slash be burned the first opportunity after cutting has taken place,

NATURAL STOCKING OF YOUNG DOUGLAS FIR FOLLOWING LOGGING

—Photos Courtesy Pacific Northwest Forest Exp. Sta.

the temperature drops frequently to as low as —34° or —40° F.

Reproduction

Douglas fir is a tree producing an abundance of seed, usually producing some every year with especially good local seed years at intervals of three or four years. Its power to reproduce itself from seed is very great. New growth starts altogether from seed, and after logging, or a fire, if left to itself a new crop will usually result. The prime requisite of obtain- either in the spring or fall, in order to reduce the fire hazard, and that special care be taken to prevent subsequent fires on the cut-over area. If this rule is practiced, a satisfactory stand of young growth should be obtained in the course of five or six years.

Growth and Yield

Growth

As a mature individual tree in its region of best development, Douglas fir is only surpassed by the *Sequoias*

in California in maximum height and diameter. Exceptional trees attaining a diameter of as great as 15 feet and a height of 380 feet have been recorded in the course of investigative work by the United States Forest Service, while a considerable number ranging from 300 to 350 feet have been listed. There are, however, any number of trees still to be seen towering between 300 and 325 feet in height, although those above 275 feet are quite rare. The average mature Douglas fir tree is about $3\frac{1}{2}$ to 4 feet in diameter and from 180 to 250 feet in height.

In the region east of the Cascade Range, Douglas fir is comparatively small, trees over 30 inches in diameter and more than about 130 feet tall being quite rare.

West of the Cascades in Oregon and Washington, Douglas fir makes its fastest growth. Table I shows the average diameter at breast height and the average total height of Douglas fir trees grown upon the better class of soils in this region.

TABLE I

Average diameter at breast height and average height of Douglas fir trees at various ages on good soils, Western Washington and Oregon:

Diameters based on 1807 stump analyses.
Heights based on 1648 trees.

Age	Inches Ave. Diam.	Feet Ave. Ht.
10 years	1.5	13.0
20	5.8	38.8
30	9.6	63.5
40	12.3	87.0
50	15.0	102.5
60	17.3	115.0
70	19.5	125.4
80	21.2	135.2
90	22.7	144.6
100	24.1	154.1
110	25.5	163.5
120	26.8	173.0
130	28.1	182.5
140	29.4	192.0

Growth and Management of Douglas Fir by T. T. Munger, U. S. Forest Service, Circular No. 175, Page 14, May 10, 1911.

Exceptionally fast growing trees, usually those in the open, have been noted to add annually between $1\frac{1}{2}$ inches to 2 inches in diameter at certain stages, while it is not unusual for trees between 10 and 30 years of age to add from 3 to 4 feet to their height during one year. The greater part of the height growth is made during the first 75 years; at 150 years the average tree has practically reached its maximum height.

Yield

Growing as a compact forest in practically pure stands, Douglas fir shows a remarkable yield of material compared to most species, for its age. Only the redwood in California, and its associated species, Sitka spruce and western hemlock, approach it in volume growth over any considerable areas.

For purposes of forest manageagement in the Douglas fir region, the United States Forest Service has constructed yield tables, showing the average volume per acre of fully stocked stands at various ages upon various kinds of soils, i. e., Sites I to V, where Site I data are for stands making the best growth, Site III intermediate, and Site V data are for stands making the poorest growth. Tables A to F give a summation of the volumes per acre which Douglas fir at various ages may be expected to produce, provided the forest is fully stocked.

The following figures indicate that when stands are fully stocked (no excessively large openings in the crown canopy), rather surprising yields are obtainable at a comparatively early age. This is especially important when it is known that the present standing mature timber in Oregon and Washington with an age of from 250 to 400 years is not bearing any greater volume on the average than second-growth stands may attain at about 60 or 70 years

STANDARD YIELD TABLES, SECOND GROWTH DOUGLAS FIR

Average yields per acre obtained in fully stocked, unthinned second-growth Douglas fir stands, Western Cascades of Oregon and Washington. From report by R. E. McArdle, Pacific Northwest Forest Experiment Station, Portland, Oregon, July, 1927.

A—SITE QUALITY I: SITE INDEX 200*

(Excellent Site Quality)

Per Acre

	FOR ALL TREES IN STAND							FOR TREES 11.6" IN DIAMETER AND UP					
Ave. Age	No of Trees	Ave. D. B. H. Inches	Basal Area Square Feet	Ave. Ht. Dom. & Codom. Trees Feet	Volume in Cubic Feet	Volume in Cords	Ave. Ann. Growth Cords	No. of Trees	Ave. D. B. H. Inches	Volume Scribner Rule, Bd. Ft.	Volume Int. ¼" Rule, Bd. Ft.	Ave. Ann. Growth Scribner, Bd. Ft.	Ave. Ann. Growth Int. ¼" Bd. Ft.
20 years	571	5.7	101	52	1,830	18.3	0.92	7	12.6	.....	400	.....	20
40	240	12.2	195	120	7,500	75.0	1.88	109	15.2	24,400	37,500	610	938
60	138	18.2	248	156	12,500	125.0	2.08	118	19.2	62,000	88,300	1,033	1,472
80	97	23.3	285	181	16,350	163.5	2.04	93	23.6	92,500	124,700	1,154	1,560
100	75	27.6	312	200*	19,140	191.4	1.91	75	27.6	115,100	148,900	1,149	1,489
120	63	31.1	332	213	21,090	210.9	1.76	63	31.1	131,100	165,500	1,092	1,378
140	55	34.3	350	221	22,520	225.2	1.61	55	34.3	143,500	178,000	1,025	1,272
160	48	37.2	364	226	23,780	237.8	1.48	48	37.2	153,500	188,100	959	1,175

*Site Index is the average total height of the dominant and codominant trees at 100 years.

D. B. H. is the diameter at breast height (4½ feet above ground) outside bark.

Cubic Volume is the solid cubical contents of the entire stem of the tree without bark.

Scribner Rule allows for 5/16" kerf and shrinkage allowance.

International ¼" Rule allows for 3/16" kerf and shrinkage allowance.

Volume in cords computed from McArdle's tables on the basis of 100 cubic feet equals one cord.

B—SITE QUALITY II: SITE INDEX 170
(Good Site Quality)

Per Acre

Ave. Age	FOR ALL TREES IN STAND							FOR TREES 11.6" IN DIAMETER AND UP					
	No. of Trees	Ave. D. B. H. Inches	Basal Area Square Feet	Ave. Ht. Dom. & Codom. Trees Feet	Volume in Cubic Feet	Volume in Cords	Ave. Ann. Growth Cords	No. of Trees	Ave. D. B. H. Inches	Volume Scribner Rule, Bd. Ft.	Volume Int. ¼" Rule, Bd. Ft.	Ave. Ann. Growth Scribner, Bd. Ft.	Ave. Ann. Growth Int. ¼" Bd. Ft.
20 years	880	4.5	98	44	1,550	15.5	0.77						
40	385	9.4	189	102	6,550	65.5	1.64	75	13.9	11,900	19,300	298	482
60	228	14.0	241	132	10,860	108.6	1.81	141	16.2	42,800	64,200	714	1,070
80	159	17.9	276	154	14,220	142.2	1.78	133	19.0	70,000	99,900	878	1,248
100	123	21.2	302	170*	16,610	166.1	1.66	115	21.8	90,400	124,200	904	1,242
120	101	24.0	322	181	18,340	183.4	1.53	99	24.2	105,100	140,300	876	1,168
140	88	26.5	338	188	19,590	195.9	1.40	87	26.6	116,300	152,000	830	1,085
160	78	28.9	353	192	20,650	206.5	1.30	78	28.9	125,700	161,100	786	1,007

*Site index.

C—SITE QUALITY III: SITE INDEX 140

(Medium Site Quality)

Per Acre

Ave. Age	FOR ALL TREES IN STAND							FOR TREES 11.6" IN DIAMETER AND UP						
	No. of Trees	Ave. D. B. H. Inches	Basal Area Square Feet	Ave. Ht. Dom. & Codom. Trees Feet	Volume in Cubic Feet	Volume in Cords	Ave. Ann. Growth Cords	No. of Trees	Ave. D. B. H. Inches	Volume Scribner Rule, Bd. Ft.	Volume Int. ¼" Rule, Bd. Ft.	Ave. Ann. Growth Scribner, Bd. Ft.	Ave. Ann. Growth Int. ¼" Bd. Ft.
20 years	1460	3.4	92	37	1,250	12.5	0.63	37	13.1	4,500	7,200	112	180
40	585	7.4	177	84	5,250	52.5	1.31	118	14.7	23,800	37,200	396	620
60	337	11.1	226	109	8,700	87.0	1.44	148	16.5	45,700	68,800	571	860
80	232	14.3	259	127	11,350	113.5	1.42	145	18.4	62,800	90,700	626	907
100	184	16.9	283	140*	13,270	132.7	1.33	134	20.0	75,000	105,600	625	880
120	152	19.1	301	149	14,600	146.0	1.21	123	21.6	84,500	116,500	601	832
140	131	21.1	317	154	15,610	156.1	1.11	113	23.1	92,400	125,000	578	781
160	117	22.8	331	158	16,490	164.9	1.03						

*Site index.

D—SITE QUALITY IV: SITE INDEX 110

(Fair Site Quality)

Per Acre

Ave. Age	FOR ALL TREES IN STAND							FOR TREES 11.6" IN DIAMETER AND UP					
	No. of Trees	Ave. D. B. H. Inches	Basal Area Square Feet	Ave. Ht. Dom. & Codom. Trees Feet	Volume in Cubic Feet	Volume in Cords.	Ave. Ann. Growth Cords	No. of Trees	Ave. D. B. H. Inches	Volume Scribner Rule, Bd. Ft.	Volume Int. ¼" Rule, Bd. Ft.	Ave. Ann. Growth Scribner, Bd. Ft.	Ave. Ann. Growth Int. ⅛" Bd. Ft.
20 years	3069	2.2	81	29	870	8.7	0.44	...	....	.....	.....	...	...
40	927	5.5	153	66	3,560	35.6	.89	7	12.6	200	900	5	22
60	500	8.5	195	86	5,880	58.8	.98	58	13.6	8,100	12,800	140	213
80	345	10.9	224	100	7,690	76.9	.96	114	14.6	20,100	31,800	250	398
100	271	12.8	245	110*	9,000	90.0	.90	141	15.7	31,400	48,000	314	480
120	224	14.6	261	117	9,920	99.2	.82	149	16.7	40,700	60,800	340	506
140	195	16.0	275	121	10,620	106.2	.75	149	17.7	48,300	70,000	349	500
160	175	17.4	287	124	11,200	112.0	.69	144	18.6	54,600	77,600	346	485

*Site index.

E—SITE QUALITY V: SITE INDEX 80
(Poor Site Quality)

Per Acre

Ave. Age	FOR ALL TREES IN STAND								FOR TREES 11.6" IN DIAMETER AND UP							
	No. of Trees	Ave. D. B. H. Inches	Basal Area Square Feet	Ave. Ht. Dom. & Codom. Trees Feet	Volume in Cubic Feet	Volume in Cords	Ave. Ann. Growth Cords	No. of Trees	Ave. D. B. H. Inches	Volume Scribner Rule, Bd. Ft.	Volume Int. ¼" Rule, Bd. Ft.	Ave. Ann. Growth Scribner, Bd. Ft.	Ave. Ann. Growth Int. ¼" Bd. Ft.
20 years	6920	1.3	64	21	520	5.2	0.26	...	....	.....	.....	...	...
40	1530	3.8	121	48	2,110	21.1	.53	...	....	.....	.....	...	...
60	780	6.0	154	63	3,500	35.0	.58	12	12.7	1,100	1,800	18	30
80	525	7.9	177	73	4,580	45.8	.57	44	13.3	4,400	7,600	58	95
100	403	9.4	193	80*	5,350	53.5	.53	78	13.9	9,600	15,200	96	152
120	331	10.7	206	85	5,900	59.0	.49	105	14.5	14,700	23,800	122	198
140	284	11.9	218	88	6,340	63.4	.44	122	15.0	19,200	30,400	137	217
160	250	12.9	227	90	6,670	66.7	.42	132	15.6	23,300	35,900	146	224

*Site index.

F—AUXILIARY TABLE FOR TREES 6.6 INCHES D. B. H. AND UP

Volumes Per Acre
For Fully Stocked Stands

Ave. Age in Years	VOLUME IN CUBIC FEET Site Quality					VOLUME IN BOARD FEET International ¼" Rule Site Quality				
	I	II	III	IV	V	I	II	III	IV	V
20	1,170	590	150	.....	.....	4,900	2,100	200	.....	.....
40	7,390	6,120	4,360	2,180	380	47,000	34,900	22,000	9,200	1,500
60	12,500	10,840	8,500	5,260	2,340	90,800	72,800	52,000	28,900	10,500
80	16,350	14,220	11,340	7,480	3,970	124,700	103,200	77,200	45,700	20,300
100	19,140	16,610	13,270	8,930	5,000	148,900	124,400	94,700	58,100	28,800
120	21,090	18,340	14,600	9,910	5,740	165,500	140,300	107,200	67,500	34,700
140	22,520	19,590	15,610	10,620	6,240	178,000	152,000	116,900	74,300	39,200
160	23,780	20,650	16,490	11,200	6,640	188,100	161,100	125,000	80,100	43,300

To obtain volume in cords divide cubic foot volume by 100.

of age for Site I, 80 or 90 years for Site II, and 100 to 120 years for Site III. It must be borne in mind, however, that the quality of this second-growth timber is very low when compared to the present mature stands, but it is also evident that the demand for lumber in the future will not be so exacting in its requirements for high-grade clear lumber, but that entirely different standards will be in effect than there are in force now.

Properties and Uses of the Wood*

Properties

Douglas fir varies in color from a decidedly reddish tinge to a light yellow, and on this account has been in the past classified as red and yellow fir. Second-growth, or red fir, usually has a coarser grain and contains a large proportion of the dark-colored summer wood. It is obtained from younger trees (the so-called second-growth timber) or from the heart of older trees. Yellow fir is the soft, fine-grained wood obtained from the outer portion of mature trees. Tests by the United States Forest Service on bridge stringers show that the red variety is slightly stronger than yellow fir, while on car-sills and small clear specimens yellow fir shows a slight increase in strength. However, for all practical purposes, the difference in strength is not enough to warrant a discrimination in favor of either red or yellow fir.

The wood is strong and hard, not very heavy, and fairly durable. The spring and summer wood vary greatly in density—the spring wood is soft and spongy and almost white in color, while the summer wood is hard and flinty and very dark. The grain varies from as few as four or five rings to the inch to as many as 45 or 50.

Green Douglas fir wood contains a moisture content of from about 25 per cent to 35 per cent, and ranges in weight from about 32 pounds to about 45 pounds per cubic foot (2 2/3 pounds to 3 3/4 pounds per board foot). When air dried the moisture content drops to about 15 per cent to 18 per cent, and the weight down to about 28 pounds to 32 pounds per cubic foot (2 1/3 to 2 2/3 pounds per board foot). Rail rates on Douglas fir lumber are based on a weight of 3500 pounds per M. board feet green, 3000 pounds rough

*For information in greater detail the reader is referred to Forest Service Bulletin 88, Properties and Uses of Douglas Fir, by McGarvey Cline and J. B. Knapp.

dry, and 2500 pounds per M. board feet dry surfaced.

Compared to other softwoods, or evergreens, Douglas fir, with Southern longleaf pine, according to their breaking strength, stands at the head of the list. In the next group are western hemlock, western larch, loblolly pine and shortleaf pine; and the weakest group are the spruces, Norway pine, tamarack, and the balsam firs.

Uses

Douglas fir is manufactuerd into almost every form known to the sawmill operator, and much round or hewed timber is used which never passes through a sawmill. These may be enumerated as piling and poles, mine timbers, railway ties, bridge and trestle timbers, car material, all kinds of lumber for houses, furniture material, boats, cooperage stock, boxes, tanks, paving blocks, and pulpwood, fuelwood, etc.

By far the greater amount of material is sawn into lumber.

Enemies of Douglas Fir

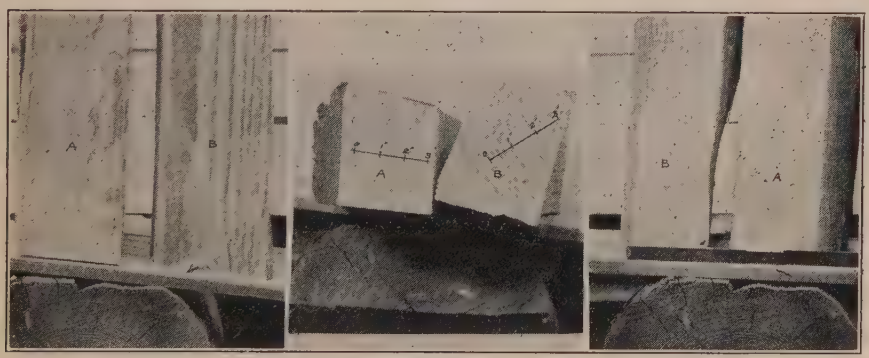
Douglas fir up to the time of its maturity is quite free from all sorts of diseases, injuries, or insect attacks.

*Fungi**

The amount of decay in Douglas fir trees up to about 150 years of age is relatively small, but in mature and overripe timber there is a great deal of defect due to decay, extending in some cases to as high as 50 per cent of the stand. Decay in trees is induced by parasitic fungi which enter the tree from the outside through an injury or dead branch, and growing and feeding upon the wood.

Four species of fungi are responsible for practically all of the decay in Douglas fir. The decays caused

*For a more detailed account see "A Study of Decay in Douglas Fir in the Pacific Northwest," by J. S. Boyce, U. S. Department of Agriculture, Bulletin No. 1163.



YOUNG GROWTH COARSE—OLD GROWTH FINE

Cross sections from the same piece of a fir tree are shown at right and left. Left, the cutting was made tangentially—"slash" or "flat" grain. Right, radically —"straight" or "vertical" grain.

A—Illustrates extremely slow growth. Taken from outside portion (with bark) averaging about 40-50 rings per inch; B—Showing fast growth. Taken from center of tree, averaging about five rings per inch.

A—Shows portion of tree from which clear lumber is cut; B—portion from which lumbermen cut commons.

B—Area of common lumber.

—Photos, Courtesy U. S. Forest Service.

by the four fungi are confined to the heartwood. These fungi are the ring scale fungus (*Trametes pini*), velvet top fungus (*Polyporus schweinitzii*), quinine fungus (*Fomes laricis*), and rose-colored fomes (*Fomes rosens*).

Of the above fungi, the ring scale fungus, also called conk rot, is by far the most damaging, and is responsible for the greatest amount of cull in Douglas fir. This disease is not confined to any one portion of the bole but extend commonly throughout the tree. The decay is usually quite extensive in an infected tree, particularly in the merchantable portion. The other three rots are of relatively minor importance, except that the velvet-top fungus, or red-brown butt rot, aids in the tendency of infected trees to windthrow by being broken off at the butt. This latter fungus is the typical butt rot, the decay of which, however, rarely extends higher than about 12 to 16 feet above the stump.

Insects

A number of insects live in the wood, bark, foliage, and cones of Douglas fir, but only one of these, the Douglas fir bark beetle (*Dendroctonus pseudotsuga*) is a serious enemy of the tree, and then only to a minor extent. This beetle, working in the cambium, attacks almost exclusively only the second-growth trees, usually when they are 60 to 80 years of age. This occurs in relatively small areas only, there being rarely more than a dozen or two dozen trees attacked in one clump; as a rule most all the trees attacked die, although some of them manage to recover. The area attacked in any one stand, or locality, however, is very insignificant. Mature Douglas fir trees are hardly ever attacked by bark beetles.

Fire

Fire is one of the worst enemies of Douglas fir, especially in its earlier years. Even through its second-growth stage, a ground fire will cause considerable damage, while a crown fire running through the tops of the trees in either mature or young stands, will invariably kill off practically the entire stand. Fire, therefore, must be effectually prevented in order that the forest may be perpetuated, and special care should be taken on recently cut-over areas so that constantly recurring fires be prevented in order that a sufficient amount of young growth may be had for a new crop.

The Redwoods

THE two species of the genus *Sequoia,* commonly called the redwoods, are noted for their extremely large sizes and to the limited area in which they are found. The true redwood, *S. sempervirens,* of great commercial importance, is a product of the Coast range in northern California and southern Oregon; the other species, known as bigtree, *S. washingtoniana,* is confined to a much more limited area on the western slopes of the Sierras, in disconnected patches, in central California.

The *Sequoias* are the largest known trees in the United States, and bigtree is easily the largest conifer in the world. From the viewpoint of lumber manufacture only redwood is of commercial importance.

Redwood

Sequoia sempervirens

Redwood is the largest conifer of commercial importance in the world. It is found in a comparatively narrow belt, rarely more than 30 miles inland from the Pacific coast, usually on the seaward side of the Coast mountains, in northern California and the extreme southwestern portion of Oregon. It ranges in elevation from near sea-level to about 2500 feet. It is essentially a tree of the fog-belt where there is an abundanec of atmospheric moisture throughout the greater part of the year, and it shows a preference for deep, well-drained soils. The best commercial development is attained north of San Francisco bay, the redwood industry being confined to that portion extending northward from northern Sonoma county through Mendocino, Humboldt, and Del Norte counties in northern California, and a short distance over the line into southwestern Oregon.

Redwood occurs both in pure and mixed stands. Pure stands are usually only found on the better soils, such as protected flats and benches along the larger streams. As such, redwood forms forests of great density, with trees of large size. In mixed forests Douglas fir and tanbark oak are its most common associates (except in damp places), these being characteristic upon the upper slopes. On the lower slopes western hemlock is its principal associate; while along the high river flats there are found Sitka spruce, Port Orford cedar, western hemlock, and lowland white fir in mixture with redwood. Other species occurring with redwood to a lesser extent are western red cedar, yew, red alder, cascara, knobcone pine, laurel and cypress.

Growth

Mature redwoods attain great sizes, average trees being from 200 to 275 feet in height and eight to 12 feet in diameter. Exceptionally large trees are 325 to 350 feet tall and up to 18 or 20 feet in diameter.

The bark of redwood is of dark cinnamon-brown color, on old trees being from eight to 10 inches thick at the base, very deeply and widely furrowed and ridged. Trees are usually buttressed at the bases, this even being a characteristic of trees in the younger ages. Higher up the bole is full and round, with but a gradual taper. Trunks of forest grown old trees are clear of limbs for 80 or 100 feet; crowns of younger trees are narrowly conical extending quite close to the ground. The leaves are flat, sharp-pointed, stiff, about

one-half to one inch long. On the lower branches and on saplings they stand out in decidedly two-ranked positions; on the main stem they are usually rather short and scale-like in form, sometimes closely pressed to the branch. The foliage has a bright, deep yellow-green color. Cones ripen in one season (two seasons for big-tree), and are about three-fourths to one inch long, egg-shaped, formed of close-packed, thick, woody scales.

Redwood has the particular advantage, in addition to the usual method of producing seed, in that it is the only conifer whose reproduction by sprouts is of commercial importance. This means that young trees start from the roots of stumps of cut trees, and that they will grow to tree size in the usual course of time. These sprouts grow more rapidly than trees produced from seed, they are long-lived, and produce trees of good form.

Seed is produced in considerable quantities; however, the seed has a very low rate of germination, therefore, only sparsely reproducing by this method. Thus the greater portion of the naturally restocked redwood young growth is due to the unusual sprouting ability of this species.

Yield

The great density of the redwood forests, and the large sizes attained by the trees in these stands, is hardly conceivable by one who has not seen them. Trees from six to 10 feet in diameter, 200 to 275 feet in height, and of such density as to allow only occasional glimpses of the sun on a clear day, are a sight to behold. Average mature forests yield as a rule from 50,000 to 75,000 board feet per acre, numerous stands have cut over 100,000 board feet per acre, and exceptionally up to 400,000 board feet, while under unusually favorable growing conditions one million board feet have been taken from one acre of redwood forest.

From the standpoint of future forest production the growth and yield of second-growth redwood stands is of great importance. Studies in the redwood region show that no other species is capable of producing as great a volume and as large-sized trees in the same period of time. Its closest competitor in this respect is Douglas fir, growing in the humid climate in the western portions of Washington and Oregon.

The yield and average tree data for *fully stocked* redwood second-growth stands, for the site qualities best suited to continued timber production are given in tabulations on page 49.

Growth data for Sites II and III only are presented here because the best site (Site I) occupies only a small proportion of the redwood region, and a large part of such land may ultimately be used for agricultural purposes. It is also probable that the two poorer site qualites, IV and V, lie chiefly toward the southern limits of the redwood range, and are outside the area chiefly of interest to lumbermen and others considering the growing of timber crops. Adequate data for these poorer lands are also lacking at this time.

The figures in the tabulations are for *fully stocked* stands, such as present no large openings in the crown cover, and it must not be supposed that all redwood areas will bear such volumes at the ages given. In fact, the present average stocking in young natural redwood forests is about 20 to 50 per cent under stocked; therefore in any yield predictions as to future volumes of such young stands the figures in these tables must be

MATURE REDWOOD TREES
Note size of man (see arrow for comparative size of trees)
—Courtesy Humboldt Redwoods Association.

reduced approximately by the per cent of understocking.

Wood

The wood of redwood is light in weight, soft, moderately fine-grained, but variable from fine to coarse, straight grained, quite brittle, and purplish, clear red-brown in color. It is very durable under all kinds of exposure. This great durability, straight grain, ease of splitting and otherwise ease of working, make redwood especially desirable for a great variety of commercial uses.

Redwood is manufactured into a great variety of products, among which are lumber for general purposes, millwork, interior finish and trim, molding, siding, shingles, tanks, silos, flumes, conduits, railroad ties, mudsills for construction work, pattern stock, furniture, etc.

The wood is listed as having very little shrinkage, moderately light in weight, moderately hard, strong (as a beam or post), moderately stiff, very durable, and rather easy of being kiln-dried.

In its early years, up to about 100 to 150 years of age, redwood is not seriously affected by either fungi or insects, but is greatly subject to damage by forest fires. Old trees are very fire-resistant, due to their thick bark, but even then large fire scars, hollow trunks, and otherwise damaged trees are the cause of considerable loss in the average mature forest due to loss of good lumber. Sapling redwoods, although more fire-resistant than associating species, are sometimes killed outright; otherwise they are seriously damaged so that the bark and growing tissue are killed, causing lengthwise seams to open which provide entry for the spores of wood-destroying fungi. Redwood is practically immune from insect attacks, and it has not this problem to contend with during its life.

Bigtree

Sequoia washingtoniana

Bigtree is of interest more from the standpoint of being a museum specimen than as a commercial timber tree. This is due to its extremely large size and to the comparatively limited range to which it is confined. Specimens are found up to 25 or 30 feet in diameter and between 300 and 380 feet tall; however, the usual maximum diameters are from 12 to 15 feet with heights ranging between 250 and 280 feet.

The occurrence of this species is limited to certain well-defined groves of varying extent of from about a dozen trees upward to several thousand acres in area. Bigtree is found only on the western slopes in the Sierra Nevada, at elevations usually from 5000 to 8000 feet from southern Placer county north to Tulare county in central California. Some of these groves are in private ownership, some are in national parks, others are in national forests, while a small portion are owned by the state. In early days a considerable proportion of the privately owned bigtree was cut for commercial purposes. A considerable number of these groves are now set aside as national parks in which they will be preserved for all time from being cut.

Bigtree resembles redwood very closely in outward appearance. The trunks are greatly buttressed at the bases, and very deeply and widely furrowed, with a light cinnamon-red bark. The bark of older trees is very thick, often 12 to 18 inches or more. The crown is conspicuously conical in younger trees, with short slender branches which point upward. The leaves are sharply-pointed, rather

SITE QUALITY II

Average yields of fully stocked second growth redwood, California†

Ave. Tot. Age of Stand	No. of Trees Per Acre	Ave. Total Ht. in Feet: All Trees	Ave. Total Ht. in Feet: Dom. & Codom. Trees	Ave. Dia. at B. H. in Inches: All Trees	Ave. Dia. at B. H. in Inches: Dom. & Codom. Trees	Volume Per Acre: Cubic Feet	Volume Per Acre: Board Feet*	Ave. Ann. Growth Per Acre: Cubic Feet	Ave. Ann. Growth Per Acre: Board Feet*
20 years	980	43	49	7.2	9.0	5,100	7,400	255	370
30 ..	628	61	71	10.4	12.9	8,700	37,500	290	1,250
40 ..	489	79	90	12.5	16.9	12,400	68,000	309	1,700
50 ..	406	95	109	14.1	19.8	15,300	94,900	305	1,900
60 ..	348	110	126	15.4	21.7	17,100	115,000	286	1,920

SITE QUALITY III

Ave. Tot. Age of Stand	No. of Trees Per Acre	Ave. Total Ht. in Feet: All Trees	Ave. Total Ht. in Feet: Dom. & Codom. Trees	Ave. Dia. at B. H. in Inches: All Trees	Ave. Dia. at B. H. in Inches: Dom. & Codom. Trees	Volume Per Acre: Cubic Feet	Volume Per Acre: Board Feet	Ave. Ann. Growth Per Acre: Cubic Feet	Ave. Ann. Growth Per Acre: Board Feet
20 years	1,020	38	43	6.9	8.0	4,200	200	210	.....
30 ..	638	54	61	10.1	11.8	7,300	26,500	243	880
40 ..	500	70	78	12.1	15.0	10,400	53,100	260	1,330
50 ..	412	84	94	13.7	17.5	12,800	76,300	256	1,530
60 ..	356	98	109	14.9	19.3	14,400	93,000	240	1,550

†From Bulletin No. 361, University of California publications, Berkeley, California, Preliminary Yield Tables for Second Growth Redwood, by Donald Bruce.

*Scaled by International ¼" Rule to 5" top diameter inside bark, with ⅛" sawkerf and 1/16" shrinkage allowance, no deduction for defect or breakage. This scale compares closely with the actual mill tally of sound logs with this width of kerf.

long and spreading on their main stems; on the extremities of the stems they overlap each other, forming slender drooping sprays. The cones mature at the end of the second season; they are about two inches long, ovoid in shape, with thick, stiff cone-scales.

Very little bigtree is now being cut for commercial purposes. The wood is a rose purple-red color when cut, later becoming a dull purplish brown. It is lighter in weight than redwood, very brittle, and contains a large proportion of tannin. Trees of this species are very long-lived, estimates and ring counts of certain individual specimens placing their ages at from 4000 to 5000 years.

Western Hemlock
(Tsuga heterophylla)

WESTERN hemlock, found only in the Pacific Northwest, attains the largest size and has the greatest potential all-around value of the four species of hemlock found in the United States. The eastern hemlock *Tsuga canadensis* has for many years been one of the main sources of bark for use in the tanning industry; also, to a lesser extent, its wood has been used for rough lumber and other purposes where quality was not especially desired. The Carolina hemlock *Tsuga caroliniana* is a tree of limited range and limited use, found only in the Blue Ridge mountains from Virginia southward to northern Georgia. The fourth species of hemlock, found only at the higher limits of forest growth in the Cascade range, is the mountain hemlock *Tsuga mertensiana,* which has future possibilities for lumber and other purposes, but which has not yet been reached in present-day lumbering operations.

Botanical Characteristics

Western hemlock is an evergreen tree with soft, flattened leaves, whose branches grow at irregular intervals from each other. This irregular arrangement of branches is radically distinct from that of the regular symmetrically-arranged spacing of the Douglas fir, Sitka spruce, silver fir, noble fir, and white fir with which it is associated in the forest. In this respect, it may be confused with the red cedar only; however, the hemlock needles are distinct in their formation, and smooth, while those of the cedar are much shorter and have the effect of being roughened, due to their method of growth. A typical characteristic is the slender tip, or terminal growth, gracefully drooping downward from the tops of the crowns.

The leaves appear to grow mainly from the two opposite sides of the stems; they are flat, grooved on their upper sides, with a rounded tip. They vary in length from about one-half to one inch, and are a deep, glossy, green color.

The cones are small, usually about one inch in length, being smaller than those of any of its associates, except the red cedar.

The bark is comparatively thin, rarely ever more than about $1\frac{1}{2}$ inches in thickness. It is hard and deeply furrowed on older trees; the ridges are wide, flat, and irregularly connected with one another by narrow cross-ridges; it is dark russet-brown, tinged with red. On younger trees it is thin, finely scaly, and of lighter russet-brown color.

Range and Distribution

Western hemlock is common throughout the Pacific coast forests from Alaska to northern California. Its principal range is on the moist and cool western slopes of the Coast ranges, Olympic mountains, the Cascade range in British Columbia, Washington, Oregon and northern California, along the coast of Alaska, and the western spurs of the Rocky mountains in southeastern British Columbia, northern Idaho and Montana. Its principal commercial range is in the western portions of Washington, Alaska and British Columbia and northwestern Oregon.

The distribution of hemlock indicates clearly that its chief requirement

A STAND OF SECOND-GROWTH HEMLOCK, ABOUT 110 YEARS OLD, ON THE SNOQUALMIE NATIONAL FOREST, WASHINGTON

Measurements in this stand by the U. S. Forest service, covering 15 sample acre plots, showed a volume of approximately 100,000 board feet per acre. This illustrates the class of hemlock timber that can be raised in the Pacific Northwest.

—Photo by U. S. Forest Service.

is a cool and moist climate. Its best growth and development, and the largest bodies of timber, are found where the annual precipitation is not less than about 70 inches, a great deal of this coming in the form of heavy fog and mist. It is not abundant, nor does it attain any size, at the higher elevations where the extremes of climate are more marked. Hemlock is a tree that finds its best development in a region of heavy moisture and an equable temperature.

Other trees found associating with the hemlock are Douglas fir, western red cedar, Sitka spruce, silver fir, lowland white fir, cottonwood, alder, and maple at the lower elevations; at the higher elevations are found noble fir, western white pine, Alaska cedar, mountain hemlock, and in southwestern Oregon and northern California it is found rather sparingly with Port Orford cedar and redwood.

In southeastern Alaska, the coast of British Columbia, and the western portions of Washington, it is found in practically pure forests over considerable areas, where other species are almost entirely lacking. It is in such pure forests that hemlock attains its best quality and greatest volume.

Reproduction

Western hemlock is one of the most prolific seed producers of the trees found in the Pacific Northwest. Some seed is produced every year, and heavy crops are produced at rather frequent intervals. The seeds are small, of very light weight, winged, and are very widely scattered by the wind. They take hold freely upon all moist sites, such as moist duff, decaying logs, and stumps; seedlings are also found upon the bare, burned-over land which is not subject to excessive drought conditions. In the moist, dense woods, the survival of seedlings is very high, although very slow growth results; on the more open places, such as on cut-over lands, where they are subject to direct sunlight and drying winds, the mortality of young growth is very high, probably not over 15 to 25 per cent of those starting will survive two full growing seasons.

Young seedlings are very tolerant of shade, but dense shade is rather detrimental than beneficial, since the growth is very slow and poor quality trees are formed. The best conditions for reproduction and the future development of hemlock are such as provide a sufficiency of moisture at all times, partial shading in the first two or three years, and full top-light from then on until maturity.

Growth and Yield

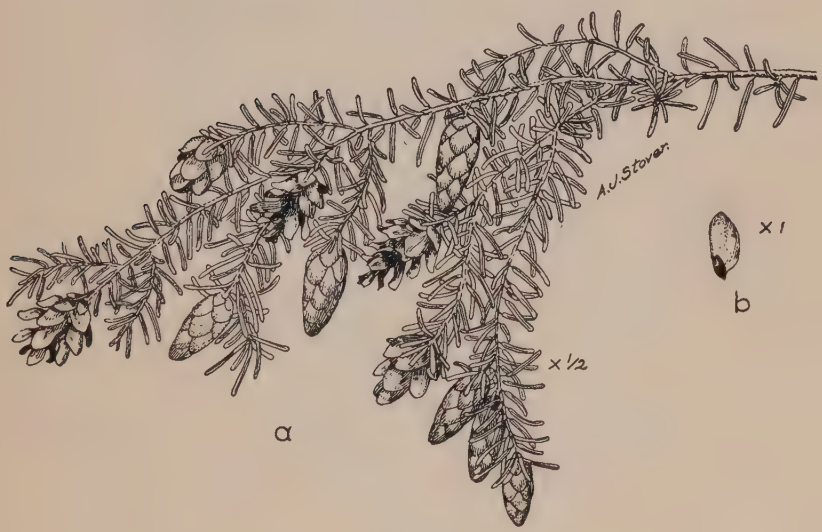
Hemlock makes a fairly rapid, even growth until maturity is reached. This results in a rather fine even-grained wood, which has no decided contrasts between the so-called spring and summer wood, such as is found in the exceedingly rapid-grown yellow pines and Douglas fir.

Trees, as a rule, have a maximum size of from three to four feet in diameter and about 200 to 225 feet tall. Larger specimens have been found, but trees over five feet in diameter have been exceedingly rare. Hemlock is a long-lived species when compared to tree growth generally, but in its habitat it has a rather short life when compared to the Douglas fir, red cedar, Port Orford cedar or redwood. Trees over 500 years old are rare, and this age may be considered as its maximum under normal conditions of growth.

Hemlock attains its best growth and development in pure stands, or in mixture with other species, in what are termed even-aged stands. As an individual in such a forest, it is one of the rapid growing species of the

coastal region, comparing favorably with the growth of any of its competitors under the same conditions of soil, exposure, precipitation, etc. Since it grows under a wide range of physical conditions, it has an exceedingly wide range in height, diameter, and volume growth. When grown in the shade as an understory tree in a forest, its growth is decidedly slow and the resultant trees are short, heavy-limbed, and of poor quality, subject to disease and other damage. As dominant or co-dominant trees in even-aged forests, either in pure or mixed stands, it attains a fast growth and forms tall slender boles, with short narrow crowns. Such trees have rather full boles tending to be cylindrical in form, giving a high volume for their diameter. Here the limbs are small, they prune themselves comparatively early in life, and a higher grade of lumber is obtained from trees grown under such conditions.

The following table illustrates the great differences in the growth of hemlock seedlings grown under the two widely different conditions. Those grown in the open, under full toplight, far outstrip those grown in the forest under cover of the older trees.



WESTERN HEMLOCK *(Tsuga heterophylla)*

a. Fruiting branch showing ripened cones with reflexed scales and also showing unopened cones. Note peculiar twist at the base of each leaf stem.

b. Winged seeds.

(x indicates scale of reduction)

—Photo Courtesy Oregon State Board of Forestry.

*Seedling Height Growth**

Age in Years	Grown in Open Height in Feet	Grown in Forest Under Cover Height in Feet
1	0.10	0.10
2	.40	.20
3	.94	.30
4	1.59	.40
5	2.58	.50
6	3.54	.60
7	4.52	.70
8	5.51	.80
9	6.50	.90
10	7.52	1.00
15	....	1.60
20	....	2.30
25	....	3.50
30	....	5.00
35	....	7.20

The foregoing table shows that it takes a shaded hemlock 35 years to attain a height which an unshaded tree reaches in 10 years. Hemlock growing in even-aged stands, in the open, has a maintained height growth of approximately one foot each year after the third or fourth year. Preceding this, its growth is somewhat slower, or about one foot in the first three years. Hemlock, which has its start in such even-aged, young stands, where it is accorded full top-light, attains its best development as a forest type and also produces the highest quality of lumber.

The growth of individual trees, after going through the seedling stage, is remarkably regular both in diameter and height. The diameter growth especially shows no great differences between the early decades and in later years. This regularity is brought out in Table I, page 55.

It is seen that the average diameter growth is greatest in the early years, being fastest from the tenth to the twentieth years, after which there is a very gradual decrease. This decrease in diameter growth is so gradual that even at 300 years of age the average growth is still 0.11 inches per year, at which period hemlock has an average diameter of 41.3 inches (outside bark) at breast height (4.5 feet above ground).

Height growth is at its best between 20 and 30 years, although up to 40 years, it is still close to two feet per year. From the thirtieth year on, however, there is a steady decrease in the yearly growth, it being almost negligible in later years, being only 0.14 inches at 300 years of age.

The yearly growth in volume shows a steady increase in later years, and hemlock does not reach its highest point until the 210th year, when it is putting on wood at the rate of 20.4 board feet per tree per year. At this age, hemlock has an average diameter of 31.0 inches and a height of 173.3 feet. From this time on, the yearly volume growth is slowly decreasing, so that at 300 years it amounts to 19.4 board feet per year.

Western hemlock, growing in even-aged practically pure stands (with only a small percentage or no other species present) produces a volume of timber per unit area about equal to that produced by competing species, such as Douglas fir and Sitka spruce, under the same soil, topographic, and climatic conditions. Such even-aged stands of hemlock as have been measured give indications of as high a volume production upon the better sites as is obtained by these other species.

It is as an even-aged forest that hemlock will be grown in the future, probably in mixture with a varied amount of Douglas fir, red cedar, Sitka spruce, silver fir and noble fir. On some areas, pure stands of hemlock will occur and such pure stands as have been measured have been found to produce the following volume Table II, page 56.

The volume per acre for the stands

*Based on data by U. S. Forest Service: Western Hemlock: Its Silvicultural Characteristics, Properties and Uses. — The Timberman, October, 1914.

listed is for the entire contents of the trees, with no deduction for breakage or defect. Under present standards of utilization, and making deduction for breakage and defect, these figures should be reduced between about 3 and 10 per cent, the lower reduction being made in the younger stands where there is practically no defect as yet. The most striking point brought out in the foregoing is the fact that stands containing a volume of over 100,000 board feet per acre occur; and, as relating to the Pilchuck River tract, that this volume is attained at about 100 years of age, or at the rate of 1000 board feet per acre per year. These volumes, however, can not be said to occur over large areas of timber, where openings and thinly-stocked areas tend to lower the average, but they do indicate what may be obtained in natural stands of good stocking where there are no openings.

These yields are for stands growing on what may be considered the best, or most favorable sites, for the production of forest crops; therefore, upon the poorer sites at the higher elevations, it is probable that not more than about one-half this volume can be obtained.

*Properties and Uses of the Wood**

The wood of western hemlock is moderately strong, of fine, even grain, rather light in weight and color, and odorless when dry. It is soft enough to machine easily, yet is of sufficient hardness and firmness to wear well and to take a good polish. Hemlock contains a relatively high percentage of moisture when green, especially in butt logs of mature timber, but it seasons readily under proper drying conditions without abnormal shrinkage. It has a very attractive grain when cut tangentially, takes paints, stains and glue well, retains its knots firmly, and has little tendency to split in nailing, except when cut in very thin pieces.

Strength tests show that hemlock is next to Douglas fir and longleaf pine for bridge stringers in the green condition, having a rating of 88 per cent

*For information in greater detail see "Mechanical Properties of Western Hemlock," O. P. M. Goss; U. S. Department of Agriculture Forest Service Bulletin No. 115, and "Western Hemlock; Its Forest Characteristics, Properties and Uses," by E. J. Hanzlik and H. B. Oakleaf; The Timberman, October, 1914.

TABLE I

AVERAGE RATE OF DIAMETER, HEIGHT AND VOLUME GROWTH OF WESTERN HEMLOCK (EXCLUSIVE OF SUPPRESSED TREES GROWN IN AN UNDERSTORY)

(Based on 530 to 552 tree measurements)

Age Years	Ave. Diam. at Breast Height (Outside Bark Inches	Ave. Annual Diameter Growth in Each Decade Inches	Average Total Height Feet	Ave. Annual Height Growth in Each Decade Feet	Average Volume Board Feet	Ave. Annual Volume Growth in Each Decade Board Feet
10.....	0.8	0.08	7.5	0.75	.....	....
20.....	3.3	0.25	24.3	1.68	.....	....
30.....	5.6	0.23	46.0	2.17	.....	....
40.....	7.6	0.20	65.1	1.91	110	....
50.....	9.5	0.19	80.3	1.52	150	4.0
60.....	11.2	0.17	93.2	1.29	204	5.4
70.....	12.8	0.16	104.4	1.12	268	6.4
80.....	14.3	0.15	114.3	0.99	344	7.6
90.....	15.8	0.15	123.0	0.87	432	8.8
100.....	17.2	0.14	130.7	0.77	534	10.2
110.....	18.5	0.13	137.5	0.68	650	11.6
120.....	19.8	0.13	143.5	0.60	779	12.9
130.....	21.1	0.13	148.7	0.52	923	14.4
140.....	22.4	0.13	153.3	0.46	1,081	15.8

against 100 per cent for Douglas fir. For air-seasoned material, hemlock has a relatively greater strength, which is attributed to the effect of the knots which apparently do not weaken the timber in seasoning hemlock to the same extent as Douglas fir.

Hemlock products enjoy a wide range of use, both as rough and finished lumber, and in the form of specialized products.

Rough lumber is used as common boards, dimension for house construction, and timbers principally.

Finished products are such as planing mill stock; mostly flooring, finish, bevel siding, ceiling, drop siding, rustic and shiplap. The wood is exceptionally well suited to this class of material, since it is soft enough to be easily machined and yet hard enough to give a smooth surface when dressed.

Other products into which hemlock appears on the market are in the form of boxes and crates, sash and doors, furniture, woodenware, caskets, barrels and candy pails, ladder stock, and all classes of cooperage.

A considerable percentage of hemlock logs go to pulp mills for manufacture into wood pulp. Both the mechanical and chemical (sulphite) processes are used. With certain percentages of cottonwood or spruce pulp, excellent papers are manufactured.

Western hemlock bark is well suited for the production of tannic acid for use in the tanning industry. The amount of bark used for this purpose at the present time is very small, due to the few tanneries in operation on the Pacific coast. Approximately two-thirds of the bark used annually in this region is hemlock bark, and with the expansion of the tanning industry on the coast, there are unlimited possibilities as far as the question of a suitable bark supply is concerned.

The bark of western hemlock is somewhat thinner than that of the eastern hemlock, but it contains a greater proportion of tannin, the western bark averaging about 12 to 15 per cent, the eastern from 10 to 13 per cent. It is usually reckoned where bark-peeling operations are being conducted, that a quarter of a cord of western hemlock bark is equivalent to a thousand board feet of logs, which will yield about 90 pounds of tannin. At the rate of one-fourth of a cord of bark per 1000 feet of logs, a well-stocked stand of western hemlock should produce about 15 to 25 cords of bark per acre.

TABLE II

YIELD PER ACRE OF FULLY STOCKED, EVEN-AGED STANDS OF WESTERN HEMLOCK IN WESTERN WASHINGTON

Locality	Average Age of Stand Years	Average Volume Per Acre Board Ft.	*Average Diam. 12" and Over Inches	No. of Trees 12" and Over Per Acre	No. Trees Between 2" and 12" Per Acre	Total Number of Trees Per Acre
Washington—						
South Bend.....	...	57,243	19.0	95	117	212
Pilchuck River—						
Snoqualmie National Forest....	107	107,558	19.5	139	24	163
Cathlamet	170	114,209	27.1	73	153	226
Montesano	250	115,882	27.9	72	179	251
Aloha	244	117,722	24.4	103	171	274

Data by U. S. Forest Service—The Timberman, October 1914.

*Volume in board feet for all trees 12" in diameter and over utilized to a top diameter of 8" inside the bark.

Western Yellow Pine
(Pinus ponderosa)

WESTERN yellow pine, *Pinus ponderosa,* is a tree typical of the dryer regions and the higher elevations of the western United States. It is found over a wide expanse of territory, from the interior of British Columbia southward to northern Mexico, and from the Pacific coast eastward to the central portion of South Dakota. It is found in every state west of the Great Plains region, and in many of them it forms the principal and most valuable tree.

Extensive cutting in western yellow pine has developed a wide market for its products, and until the past few years these were sold under various trade names, such as western pine, western soft pine, Oregon white pine, California white pine, etc. In recent years the name "Pondosa pine" has been adopted by the Western Pine Manufacturers' association, which has it principal field of operations in Oregon, Washington, Idaho and Arizona.

In the Pacific coast region western yellow pine is found over large areas east of the Cascade range in Washington and Oregon, in southern Idaho, the Siskiyou mountains of southern Oregon, the Sierra Nevada of California, and in the northeastern portions of California.

In these states there is estimated to be a volume of some 150 to 200 billion feet, board measure. The average stand per acre varies from about 5000 board feet to as high as 35,000 to 40,000 board feet per acre. The stands of highest volume and of the best quality occur in southern Oregon and in northern California. The great differences found in the volume and quality of yellow pine are due primarily to the great variety of climatic and soil conditions under which it is found. The best development of this species, both as an individual tree and as a forest type, is in the comparatively mild and moist climatic zone of the Siskiyous and the Sierras; while upon the less humid and severer interior situation of Oregon and Washington, with their largely prevailing volcanic soils, the growth and development of this species is not so favorable.

As a forest type yellow pine forms practically pure stands over large areas. Typical of these are such as are found in the Central and Blue mountain regions of Oregon, vast areas in northern California, and pine forests of Arizona and New Mexico. Variously associated in the mixed stands with yellow pine are found Douglas fir, western larch, lodgepole pine, white fir, sugar pine, and incense cedar.

Tree Description and Characteristics

Western yellow pine varies greatly in its appearance in different parts of its wide range. The yellow pine stands of the Black Hills region are quite different from those in the southwest, and those in turn are unlike those of northern California, Oregon and Washington. The appearance of mature, or old trees, is quite distinct from that of the immature, or "bull pine" class, so that in many localities these two age-classes have been wrongly designated as two separate species.

Mature yellow pine trees have a distinctive appearance in the forest.

In the Pacific coast region, due to the great differences in their habitat and the climatic conditions under which they grow, mature trees have a range in height of from about 75 feet to over 200 feet. Diameters run all the way from about 16 or 18 inches on the poorest sites to between five and six feet upon the best. These best sites occur in the central and northern portions of California, becoming poorer to the north, east and south. The altitudinal range also has a great effect upon the rate of growth of yellow pine, as for example at the lower elevations in its northern range, as upon the east slopes of the Cascades in Washington, excellent stands occur comparable to those found further south. The average size at maturity is about three to four feet in diameter and 130 to 150 feet in height. For the states of Oregon and Washington the average sizes will run somewhat smaller, about three feet in diameter and 110 feet in height.

Yellow pine is usually the predominant tree in the forest type in which it occurs. It is usually comparatively easy to pick out the mature trees by their flat, reddish-yellow color bark, which is broken into rather large, irregular plates. The bark on old trees is generally about one inch thick, and around very old trees may be found mounds of the typical flat scales which fall off the trees as they approach over-maturity. These have a rounded or flat-topped crown; the branches being somewhat heavy, twisted and gnarled. The foliage is rather thin and open, of a light-greenish color; the needles, borne three in a cluster, are usually from four to six inches long, although on exceptionally good sites they sometimes are considerably longer.

Second-growth, or "bull pines", are quite different in appearance. Their bark is thicker, $1\frac{1}{2}$ to 3 inches at the butt, hard, dark and roughly furrowed; the crowns are long and conical, deep green in color, with dense foliage. These are the thrifty growing trees, up to about 150 years

HEAVY YELLOW PINE STAND ON BEAR VALLEY SALE AREA, MALHEUR NATIONAL FOREST, OREGON
—Photo by U. S. Forest Service.

of age, sometimes attaining diameters up to 36 or 40 inches.

The cones are of medium size, three to five inches long, and about two to two and one-half inches thick. It takes two seasons for the cones to mature, as opposed to one season for Douglas fir, hemlock, spruce, or the balsams. Heavy seed crops are at comparatively long periods, usually

CROSS SECTION OF WESTERN YELLOW PINE SHOWING INCREASED GROWTH AFTER CUTTING OF MATURE TIMBER.

—Photo by E. H. Morton, Courtesy U. S. Forest Service.

five to eight years, depending upon the site, climatic conditions, and other factors. The seed has a good germination per cent, but seedling losses during the first year are high, especially upon the open, exposed situations. The best survival is obtained under forest conditions where the shade is not too dense, whereby the evaporation of the soil moisture is retarded and excessive temperatures are modified by the influence of the adjacent trees or brush growth.

Reproduction

Yellow pine forests are best perpetuated through what is termed "advance reproduction". This is a method of natural reforestation whereby nature provides for a future crop of trees by young growth being established under the mature trees in the virgin forest; or whereby through the aid of forestry practice natural seeding is encouraged by the proper opening up of the more dense second-growth stands.

Providing that fires are kept out of the virgin forests, such as are found in the pine region, there is usually an advance crop of seedlings ready to replace the mature timber when it is cut. "Light-burning" does not allow this advance reproduction to become established, as the tender seedlings and saplings are unable to resist the scorching and the heat of the fires. Therefore, broadcast burning of any sort, either in the uncut stands or on cut-over areas, is not to be tolerated in any program for the perpetuation of the yellow pine forests in the western United States. This broadcast burning results in two things detrimental to forest growth; first, it destroys the advance reproduction; second, it impoverishes an already not too fertile soil.

The rate of growth of these advance seedlings is not very rapid because of their being shaded by the mother trees, but upon being opened up to full top light by cutting operations they make good recovery and a greatly increased growth. These advance seedlings take as a rule 15 to 20 years to attain a height of three or four feet; these same seedlings after being opened up to full light will make an equal growth in from three to five years.

It is exceedingly difficult to obtain satisfactory reproduction of yel-

low pine seedlings on an area which has been burned. Instances are found where eight to ten years after a fire practically no seedlings have become established, and it is estimated that it takes 20 to 30 years, even under favorable conditions for tree growth, to obtain a satisfactory stocking of yellow pine seedlings. The value, therefore, of protecting this advance growth, ranging in height from a couple of inches to ten or 15 feet, may well be appreciated when one has seen the barren areas wherever a fire has been allowed to run through a pine forest or over cut-over areas in the pine region. It is this problem of the seeding habits and seedling survival that requires such widely divergent systems of forest management in the handling of the old-growth Douglas fir stands west of the Cascades, where reproduction is obtained *after* cutting as opposed to the yellow pine region where the reproduction is obtained *before* cutting.

Growth and Yield

The present-day stands of yellow pine timber, in the Pacific coast region, vary in volume from about 7000 board feet to as high as 35,000 or 40,000 board feet, per acre. As a rule they are open, resulting in forests easily accessible and park-like in character. These pine forests are, as a rule, considerably understocked, and are bearing only about one-third or one-fourth of the volume that will be possible under forestry practice in the future.

The future yields of second-growth yellow pine stands have been found to be exceptionally high, as compared to the volumes found in the present mature stands. Investigations show that stands, upon sites that are typical in eastern Oregon, at about 140 years of age should have a volume of about 35,000 to 40,000 board feet per acre (Scribner log scale), as compared to a present average of 10,000 to 20,000 board feet in the average mature stand at the present time. Upon the better sites, such as are found in northern California and southern Oregon, these data show that volumes as high as 60,000 to 65,000 board feet per acre are attainable; upon the poorer sites the yields should be about 15,000 to 20,000 board feet per acre where now the mature timber runs from 7000 to 10,000 board feet.

Properties and Uses of the Wood

The wood of western yellow pine varies greatly with the character and age of the tree from which it is produced. The "bull pine" trees, and the centers of mature trees, have a coarse-grained, comparatively hard and heavy wood, with a hard summerwood and soft springwood. This makes a rather low grade of lumber, but is well suited to construction work, and for general uses where light, clear stock is not necessary. The large trees, especially the slower growing ones, produce a soft, even-textured, light weight wood, which is obtained from the outer portions of the tree. This class of lumber is free from knots, is easily worked, and commands the best price. Much of this soft, clear stock is sold in competition with the white pine of the eastern United States for special purposese, such as pattern stock, etc.

The wood is not classed as especially strong; in its green condition it has a strength rating at about 70 per cent of that of green Douglas fir. The weight of 1000 board feet of green logs is from 7000 to 8000 pounds; green lumber weighs about 3500 pounds per 1000 board feet. The average shipping weight of 1000

WESTERN YELLOW PINE *(Pinus ponderosa)*

a. Detail of twig showing leaves, three in a bundle and with a persistent sheath at the base of each bundle.

b. Detached matured cone showing reflexed scales with heavy tips.

c. Sketch showing "broken cone" features.

d. Winged seed, both sides.

e. Seed without wing.

(*x* indicates scale of reduction)

—Photo Courtesy Oregon State Board of Forestry.

board feet, one-inch thick, air-dry lumber (rough), is rated at 2400 pounds.

Yellow pine lumber, sold as Pondosa pine, is used for practically all purposes. It is used for house construction, as for framing, siding, ceiling, panels, flooring, sash and door stock; for special factory products, pattern stock, etc. Large quantities of boxes are manufactured each year for fruit shipments from the states of Washington, Oregon, and California.

Western yellow pine has been found to have good possibilities for the manufacture of pulp and paper, especially as an adjunct for the utilization of waste pieces in connection with the sawmilling industry. With the soda process it yields about 1470 pounds of pulp per cord of wood, producing a fibre of brown color; by the mechanical process a yield of 2290 pounds of pulp is obtained, with long fibres, creamy in color. This latter process is probably suitable only for the manufacture of manila and other papers where a brown color and coarseness is not a detriment.

Enemies

The principal enemies in the production of yellow pine timber are the western pine beetle (*Dendroctonus brevicomis*) and fire.

The western pine beetle is a small insect, about one-fourth-inch long and brown in color, which bores through the bark and creates a maze of galleries in the inner bark. This series of galleries, in which are laid the eggs, eventually stop the flow of the sap, thereby causing the tree to die in the same manner as if it had been girdled by the cutting away of the bark from the wood. In the ordinary run of the insect work usually only the older trees are killed by the beetles, although all ages are attacked. The younger, more virile trees, are usually able to ward off the attack by drowning them out by an abundance of pitch; this the old trees are unable to do since very little excess pitch is produced by them. It has been found in Oregon that this so-called normal infestation is taking place continually in these mature stands, with an annual loss of about one tree to every 30 acres, or 20 trees per section. However, at times, due to reasons not yet known, these infestations become what are termed epidemic, over considerable areas, resulting in heavy losses for periods of from five to ten years. In such epidemic attacks the losses may run up to as high as 300 or 400 large trees per section each year for several years.

Another beetle causing some damage to yellow pine is the mountain pine beetle *(Dendroctonus monticolae)*. This beetle, however, works mainly in lodgepole pine, and it is only in stands where yellow pine and lodgepole pine are mixed that any damage results to the former. The damage to yellow pine by the mountain pine beetle is very limited compared to that caused by the western pine beetle.

Fires are mainly detrimental to yellow pine tree growth in the prevention of the establishment of a second crop under the mature timber. Old trees and bull pines of loggable size are commonly fire resistant, although considerable damage is done to them in the nature of fire scars, and the slowing up of their rate of growth. Crown fires are rare in pine forests, most of the fires being such as are classed surface fires, which creep along the ground usually destroying all young trees and damaging the pitchy butts of the older trees. With the control of this fire problem

the perpetuation of the yellow pine forests is greatly aided.

Other factors affecting yellow pine stands are mistletoe, a vegetable parasite which attaches itself and feeds upon the bole and limbs of the tree, and wind. The mistletoe causes swelling and deformities, and slows up the growth; however, it rarely causes the death of a tree. In certain localities the wind causes some damage over comparatively small areas at times; the topography and the nature of the soil having a great influence in the location of these wind-thrown areas.

Fungi, which cause decay in the wood, are comparatively rare and cause comparatively little damage. The principal one is butt rot, or dry brown rot *(Polyporus schweinitzii)*, which enters through butt scars and affects the lower portions of the tree. Other fungi are the ring scale fungus *(Trametes pini)*, which works in the bole of the tree, causing a rotting of the heartwood; and the chalky quinine fungus, or sap rot *(Fomes laricis)*, which causes a red heart rot with a white felt mycelium.

Western White Pine
(Pinus monticola)

WESTERN white pine is found over a wide range in the northern Rocky mountains, the Cascade range, and the northern Sierra Nevada, occurring in northern Idaho, northwestern Montana, southern British Columbia, Washington, Oregon, and northern California. It is most abundant in northern Idaho where it is found in practically pure stands and also in mixture with other species over large areas. In this region the tree and the lumber products go under the trade name of Idaho white pine, because it is only here that it occurs in large commercial quantities.

White pine is a tree of the middle and upper slopes of the mountains wherever it is found. Except in Idaho it rarely forms over 5 per cent of the timber stand, and it is seldom in pure stands. In early ages it sometimes is found covering areas of from 5 to 15 or 20 acres as a pure stand, however old trees are usually in mixture with other species. Only in the Olympic mountains and on Vancouver Island is it found close to sea level; generally in the northern portions of its range it does not occur above 3000 feet elevation west of the Cascade summit, while east of the summit in Washington and Oregon it is found from about 3000 to 6000 feet elevation. In California its altitudinal limits are from 5000 to 8000 feet. Generally in Oregon, Washington, California, and British Columbia western white pine occurs only as a scattering individual in the main stand, forming rarely more than 2 or 3 per cent of the volume.

In Idaho, where the best stands of white pine are found, it occurs at elevations of 2000 feet to 7000 feet. Here it attains its best growth in the moist valleys where the soils are deep and porous, generally upon the gentle north slopes and flats. Associating species are western larch, western hemlock, Douglas fir, Englemann spruce, western red cedar, white fir, lodgepole pine, silver fir, noble fir

and red fir, varying to some extent in different parts of its range.

The estimated stand of western white pine is from about 20 to 25 billion board feet, of which 80 per cent or so is in Idaho and northwestern Montana. In Washington and Oregon it is found mainly upon the poorer sandy soils where the associating species as Douglas fir, western hemlock or red cedar can not exist in competition with the pine.

Tree Characteristics

Western white pine is a straight tree in maturity having a long clear bole and a short, rather open, crown. It resembles the eastern white pine very closely except that the western species has stouter and longer needles and much larger cones. In the optimum region of its growth in Idaho it attains a diameter of from four to five feet and it is from 180 to sometimes 200 feet tall. Average mature forest trees run from $2\frac{1}{2}$ to $3\frac{1}{2}$ feet in diameter and from 150 to 180 feet in height. Due to the thin bark and its long full bole white pine has an exceedingly high volume for its diameter and height when compared to other species. The bark is grayish-purple in color, in characteristic squarish checks, and rarely over $1\frac{1}{4}$ inches thick. Because of this thin bark white pine is easily killed by fire. The leaves are five in a cluster, two to four inches long, and rather stouter and stiffer than those of the eastern white pine. The cones are from six to 10 inches long, sometimes up to 12 inches, and mature their seed in two seasons.

White pine reproduces from seed only, the seed crops not being very abundant, usually about two years apart. The seed germinates best on exposed mineral soil, where the young trees have the best chance for survival. However, young trees will persist in shade for some years, although full top light is required for ultimate survival and proper development. It may be classed as a moderately tolerant tree when young and rather intolerant in later life.

The perpetuation of the white pine forests depends largely upon the opening up of the old stands so that sufficient light and warmth may enter so that young trees may survive, and upon the *proper disposal of the slash resulting from cutting operations.* Briefly the measures necessary under average conditions may be stated as follows:*

1—Pile and burn all slash.

2—Leave all thrifty white pine trees below 14 inches in diameter and cedar poles under 30 feet. Leave two to six white pine trees per acre above 14 inches, and perhaps a few seed trees of other species.

3—Cut white fir, hemlock, Douglas fir, and cedar as closely as merchantable.

4—Fall or girdle all defective white fir and hemlock in order to reduce the shade on the ground and make room for white pine seedlings.

The burning of the logging slash is perhaps of the greatest importance in obtaining a new crop. With the great fire hazard left on the ground there is always the chance for all young growth to be destroyed, and it takes only one fire to offset the result of many years growth. Therefore, to safeguard the cut-over lands from the element of fire, the surest method is to pile and burn the slash, preferably all of it, but at least a minimum of 50 per cent, concentrating the work along roads, railroads and lower slopes. This slash should be burned the first fall or spring after it is produced.

*Reforestation in White Pine, by Elers Koch, Four L Bulletin, Feb., 1924.

WESTERN WHITE PINE *(Pinus monticola)*

a. Mature woody cone with stem, showing reflected scale with thickened tips.
b. Winged seed, natural size.
c. Detail showing leaves in bundle of five.
d. Diagrammatic sketch of deciduous sheath at base of leaf bundle.
(*x* indicates scale of reduction)

—Photo Courtesy Oregon State Board of Forestry.

Western white pine attains a fairly large yield of lumber, on fairly good sites in Idaho the volume for mature timber running from 50,000 to 60,000 board feet per acre, but averaging about 30,000 feet usually. Second growth fully stocked stands give yields of about 15,000 board feet per acre at 60 years, 42,000 feet at 100 years, and 54,000 feet at 140 years. Average second-growth timber over extensive areas will run ordinarily about 20 to 40 per cent lower than the above figures.

The wood of western white pine is very light and soft, not strong, straight-grained, easily worked, and light brown in color. It is stronger than either western yellow (pondosa) pine or lodgepole pine, but not as strong as Douglas fir, western hemlock, or western larch. It may be classed as only a moderately strong wood for a conifer. It is one of the most important of the western woods and is used for a great variety of purposes where strength is not a primary consideration. The wood is very similar in appearance and in its working qualities to that of the eastern white pine, for which it is now extensively used. The principal uses are for lumber, interior finish, sash and door stock, panels, match stock, pattern work, cabinet work, woodenware, etc.

Enemies

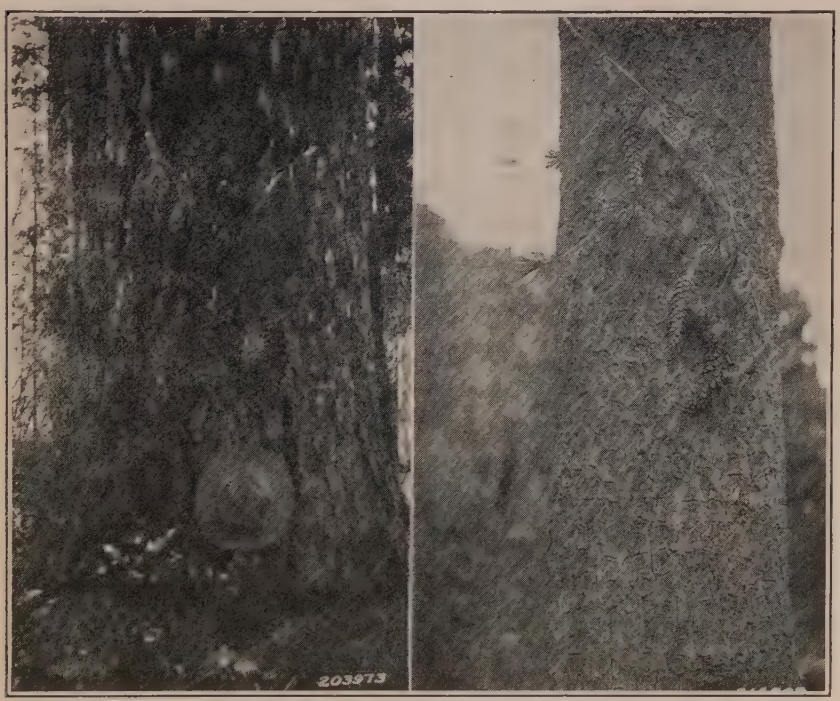
Western white pine has a number of enemies and is seriously affected by insects, fungi, and fire. Of the insects the mountain pine beetle, *Dendroctonus monticolae,* causes a great deal of damage both to old and young trees, and a considerable volume of timber is killed annually. This beetle also attacks lodgepole pine, western yellow pine, and sugar pine. It is about one-fourth inch long with a stout body, black in color. It burrows galleries in the inner bark of the tree, the main ones extending vertically, with smaller ones at right angles. These differ from the galleries of the western pine beetle, *Dendroctonus brevicomis,* which causes great damage to the western yellow pine, in that the galleries of the latter are winding, crossing and recrossing each other. Evidences of beetle attack in the trees are the small holes about one-sixteenth inch in diameter in the bark, and the accumulations of sawdust and occasionally pitch tubes covering the holes, where the beetles have entered the bark of the tree. An attack by any considerable numbers of these beetles results in the girdling of the tree by these galleries, thereby cutting off the food supply.

The most serious enemy of the white pines is the white pine blister rust, *Cronartium ribicola.* This rust also attacks the eastern white pine and other five-needle pines. It was brought over from Europe on white pine seedling shipments to the eastern states about 25 years ago, and after doing great damage to the eastern species, virtually wiping it out in many localities, this rust has found its way to the Pacific Northwest. Specimens have been found in southwestern British Columbia, western Washington, and northwestern Oregon, and the spread of this disease would be a serious menace to the growth of both the western white pine and the sugar pine in the western states.

The blister rust can only attack the pines after it produces spores on the leaves of either wild or cultivated currants or gooseberries. It grows in the bark of the pines, and within several years after infection the bark swells, and blisters form early in the spring. These are small protruding

brownish sacs, containing millions of yellow spores (seeds). These sacs break open and the spores infect the leaves of the currant or gooseberry bushes. Here the disease is seen in early summer as a yellow rust on the underside of the leaves. Here again spores are produced which in turn can only infect other currant or gooseberry bushes, but can not go directly to the pines. From this second stage on the bushes another set of spores is produced which can only infect the pines, thus completing the cycle. The disease kills the pines by working in the bark and girdling the tree. In this life cycle of the rust the common cultivated black currant is the most dangerous host plant. Others of less importance, but still very dangerous and liable to spread the disease, are the common red flowering currant, the stink or skunk currant, the common garden currants and gooseberry bushes, as well as the other wild currants and gooseberries.

The most important wood destroying fungus is the ring-scale fungus, *Trametes pini,* a trunk rot entering the tree only through wounds. It causes a reddish heart rot with white flecks or patches, with a separation of the annual rings. Others of lesser importance are the velvet top fungus, *Polyporus schweinitzii,* causing the common butt rot and entering through wounds at the base of



SUGAR PINE WESTERN WHITE PINE
Showing bark, foliage and cones. The picture of the sugar pine was taken in the Crater National Forest, in Oregon.
—Photographs Courtesy U. S. Forest Service.

the tree, and the root rot fungus, *Fomes annosus,* also causing a butt rot in the first six or eight feet of the tree.

Fire is a very serious enemy, the thin bark offering but very poor protection against this scourge. Large areas of timber have been killed outright, both ground and crown fires causing practically total loss of the living trees, because of the thin bark and the fairly high inflammable foliage which carries a heavy growth of lichens and moss. Very few trees survive any kind of a fire in the white pine forests.

Sugar Pine
(Pinus lambertiana)

SUGAR pine is confined to a rather limited range at the higher elevations of the southern Cascades, the Siskiyous and the Sierra Nevada in Oregon and California. It is found as far north as the Santiam valley in Oregon, eastward almost to the Goose lake region in southeastern Oregon and northeastern California, and extends southward into Lower California, in Mexico. The commercial range is limited to the southern Cascades, the Siskiyous of southern Oregon and northern California, and the northern Sierras. It is also found very sparingly in the Coast range of southwestern Oregon and northwestern California. Its altitudinal range at the northern limits of its range are 1500 feet to 3500 feet; its main commercial bodies are at about 4000 to 6000 feet; at its southern limits it is found at from about 8000 to 10,000 feet elevation. It is always in mixed stands, in its commercial range being associated with western yellow pine, Jeffrey pine, incense cedar, Douglas fir, white fir, red fir, Shasta fir, and lodgepole pine. Over most of its range sugar pine forms about 5 to 25 per cent of the stand, and occasionally as high as 75 per cent.

Sugar pine is the giant of the pine trees, attaining a height well up to 200 feet and diameters up to six and seven feet. Average mature trees run from 3½ to 4½ feet in diameter and 150 to 180 feet in height. The trunk is very straight with very little taper, and pruned of limbs well into the top. Typical second-growth trees, about 100 years of age have a rather hard, dark, deeply furrowed bark from 1½ to 2½ inches thick; in old trees the bark is a cinnamon or red-brown color about the same thickness, and broken into long irregular plates. The foliage is deep blue-green with a silvery tinge, the leaves are in bundles of five, about three to four inches long, and rather stouter and stiffer than those of the eastern white pine. The cones are extremely large, usually from 12 to 18 inches—occasionally 20 to 24 inches—and about four inches in diameter. The seed ripens in two seasons, is rather large, and is much sought after by squirrels and other rodents.

Sugar pine is one of the most rapidly growing trees within its commercial range, and attains a merchantable size at a fairly early age for the region and the character of the land upon which it grows. It makes its best growth in even-aged stands in mixture with other species where it can maintain itself as a dominant tree in the stand. Young growth coming up in the virgin forest under the mature trees makes rather slow

growth, averaging only about 45 feet in height at 60 years of age against a height of 80 feet for open grown trees at the same age. During the earlier periods, up to 80 or 100 years, sugar pine grows somewhat slower than its principal competitor, western yellow pine; however, after this age sugar pine forges ahead and maintains the lead until maturity. Under favorable conditions of growth trees will average about 24 inches in diameter at 100 years of age, while on the average sites in California growing under all conditions within its commercial range an average diameter of 18 inches is attained at this age.

Reproduction is from seed only; seed crops are rather frequent but the available seed supply is cut down appreciably because of being sought for food by squirrels and other rodents. Germination is best upon bare mineral soil and some shade is desirable for the establishment of seedlings during the earlier periods, although it becomes rather intolerant of shade later on in life. For the perpetuation of sugar pine after cutting operations, practically the same rules are applicable as given for western white pine: namely, to pile and burn the slash left after logging, to leave thrifty sugar pines up to about 20 or 25 inches in diameter, cut all the merchantable trees of other species occurring in the stand, and, cut and burn all unmerchantable white fir and other species to make room for sugar pine seedlings.

The wood of sugar pine is similar in most respects to that of the eastern and the western white pines and it is used for practically the same purposes. The sapwood and the heartwood are well defined, the former is white or yellowish-white, the latter is a light brown sometimes tinged with red. It is moderately strong, only moderately hard and not heavy except in its green state. It is straight-grained, moderately coarse, takes a smooth finish and has a fine texture. The wood is easily worked, does not split when nailed and takes a satiny finish. It is used largely for boxes in California; in the general markets it goes in the form of lumber, while other uses are for sash and door stock, furniture, fixtures, pattern stock, match stock, cabinets, interior finish, and general purposes.

Like the western white pine, sugar pine is attacked by the pine blister rust, but indications thus far are that it is not so easily infected as the white pine. Control steps have been taken to prevent the spread of this disease to the pine forests of California, where once started it would wipe out the sugar pine as a commercial species. The mountain pine beetle, also attacking the white pine, is a serious enemy of sugar pine, and considerable amounts are killed at times, mainly in the mature trees. Young growth is sometimes killed by the engraver beetle, *Ips confusus,* and dead tops and dead limbs of the mature trees are the result of the work of this beetle. South of the Kern river, in California, considerable loss is caused by a species of the flat-headed borer.

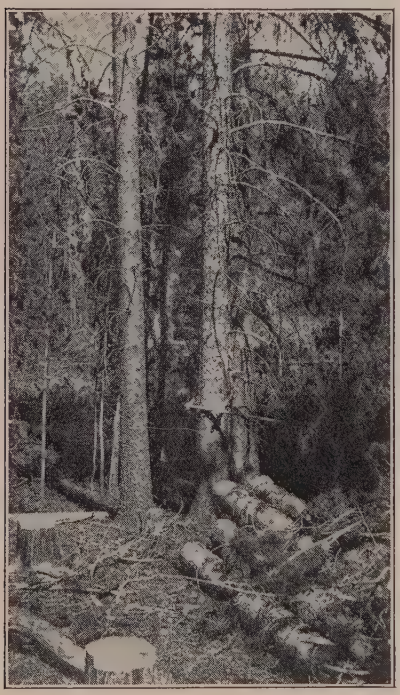
There is very little loss to sugar pine by the decay fungi and only the older trees are attacked. The principal loss is caused by the ring-scale fungus, *Trametes* pini, this, however, amounting rarely to over 3 or 4 per cent of the volume.

Due to the comparatively thick and hard bark, and to the generally humid conditions where it is found, fire is not a very serious enemy of sugar pine where ordinarily careful protection measures are taken. However, as with all other species, the

control of fire is the means whereby the forests may be perpetuated, and no let-up should be allowed in order to attain this end.

Lodgepole Pine
(Pinus contorta)

LODGEPOLE pine, also known as jack pine, is one of the most widely distributed species in the western United States and in western Canada. It is found at sea level along the shores of the Pacific ocean, and ranges from there upward

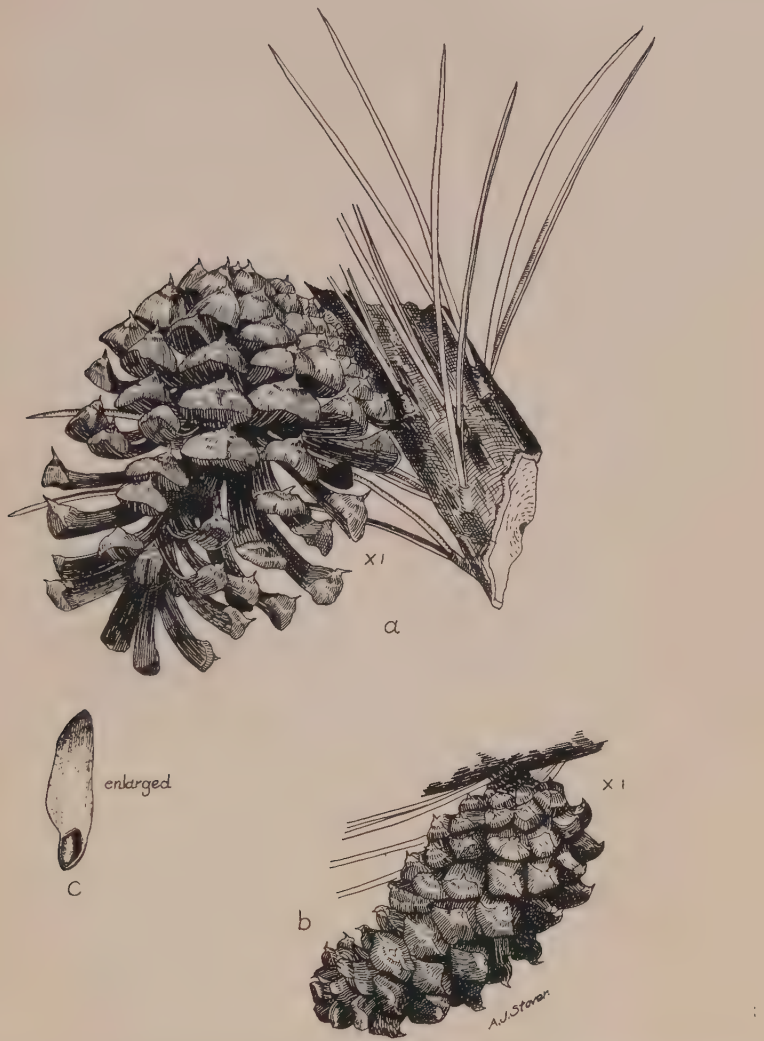


LODGEPOLE PINE IN THE BLUE MOUNTAINS, OREGON, 12 TO 14 INCHES IN DIAMETER.
—Photograph by the Author.

to over 11,000 feet in the Sierras of California, and in the Rockies of Montana and Wyoming. Its natural range extends from the Yukon river southward along the Cascades, Sierra Nevadas and San Jacinto mountains to the northern parts of Lower California; through the main ranges of the Rocky mountains to northern New Mexico; in the intermediate mountain ranges of eastern Washington and eastern Oregon; and eastward into the Black Hills of South Dakota. Its commercial limits vary from about 2000 feet to 11,000 feet; in Montana being at its best from 6000 to 8500 feet, in Colorado from 9500 to 11,000 feet, in Oregon and Washington generally from 3000 to 6000 feet, in California from 5000 to 9000 feet, while further north in British Columbia its commercial limits are from 3500 to 5000 feet.

Lodgepole pine is a small tree, as compared to the usual run of Pacific coast species, seldom 24 inches in diameter and hardly ever over 100 feet in height. Only open grown trees on rich soils, as in open meadows, attain a greater diameter, sometimes growing as large as 36 inches; but such trees are rapidly tapering, short and heavy crowned, and of no value from a commercial standpoint except for fuel wood.

The bole is usually uniformly round when forest grown, straight, only slightly tapering, and with little butt-swell. The crown is very short, rarely more than one-fourth the total height, and with small limbs. The branches die off rather early, but being rot-resistant they persist for many years, causing a considerable number of small, sound pin-knots, which lower the quality of the lum-



LODGEPOLE PINE *(Pinus contorta)*

a. Twig showing woody cone with reflexed scales, and also showing leaves, two in a bundle with persistent sheath at base of each bundle.

b. Unopened cone.

c. Winged seed, natural size.

(*x* indicates scale of reduction)

—Photo Courtesy Oregon State Board of Forestry.

ber. The bark of mature trees is thin, usually not over one-half to one inch in thickness, deep purplish-brown in color, with deep rough furrows and ridges which are sharply cross-checked. Young trees and very old ones have a very thin, smooth, finely scaly, pale-brown bark, with a grayish tinge. The leaves are found two to a bundle, from one to

three inches long, usually about two inches. The cones take two years to ripen their seeds, and are produced at a very early age. They are produced in great numbers, and remain on the trees for many years sometimes before opening and shedding their seeds. They have unusual ability to withstand great heat, and as a result after a forest fire lodgepole pine is able to seed up burned over areas before seed of other species is available.

Habits and Growth

Lodgepole pine is able to adapt itself to a great variety of climatic and soil conditions; existing at the warm, moist, low, boggy situations along the Pacific ocean to the other extreme of the hot, arid and colder situations of the high altitudes of the mountain regions. It will grow on low swamp soils, dry sandy soils, and on the rock situations at the higher altitudes. The best growth, however, is attained upon the better drained, moister situations, where there is a depth of good soil.

This species occurs in pure stands over large areas throughout its range, usually as a result of fire conditions whereby the seeding capabilities of lodgepole pine enable it to take immediate hold following a fire, to the detriment of other species. It is, however, in mixtures with other species that it attains its best development as an individual tree. When grown in pure stands, due to its heavy seeding habits, it forms very dense forests which in later life stagnate in growth, thereby forming, as a rule, large areas of dense thickets of trees, each from 4 to 8 or 10 inches in diameter. These stagnated trees have such low vitality that they are easy prey to bark beetles, which destroy large areas of lodgepole pine timber annually. However, when in mixture with other species, trees up to 14 or 16 inches in diameter are quite common, and in such stands lodgepole pine is little subject to beetle attack. Associating species are mainly Douglas fir, western larch, western yellow (pondosa) pine, Engelmann spruce, western white (Idaho) pine, white fir; over limited areas in the Cascades in addition there are found noble fir, alpine fir; while in southern Oregon and northern California additional species found with lodgepole pine are sugar pine, red fir and Jeffrey pine.

Ordinarily, lodgepole pine forests have a volume running from about 5000 to 10,000 board feet per acre; however, fully stocked stands in Montana have been found with as high as 20,000 board feet per acre at an age of about 140 years.

The rate of growth is comparatively slow, measurements in the Blue mountains of Oregon show that it takes about 100 years to attain an average diameter of 12 inches and a height of about 75 to 80 feet. On the faster growing sites, such as in the northern Sierras and in southern Oregon, lodgepole pine grows much faster, trees at 100 years of age attaining a size well up to 15 or even 18 inches in diameter and 90 to 100 feet in height.

Lodgepole pine is a prolific seed bearer, and reproduces only from seed. Little or no difficulty is found in obtaining a new crop, due principally to the great amounts of seed, and the ability to germinate and survive under exceedingly harsh climatic and soil conditions. It does not reproduce well under shade, and can not stand overhead cover for any length of time. The best stocking of young growth takes place upon ex-

posed mineral soil and on freshly burned areas. Observations of old cuttings in Montana indicate that regeneration takes place quite satisfactorily, though slower than following a fire, provided that there is sufficient light and moisture.

Cutting practice, depending upon the chances of windthrow, appear to favor either a fairly heavy selection method by taking out the largest trees to open up the stand, or a clear cut with seed trees. The latter method, however, is not recommended where there is danger of windthrow. As a rule natural regeneration should be satisfactory by either method in the course of two or three seed crops.

The wood of lodgepole pine is straight grained with narrow rings, when grown in dense stands, and with wide coarse rings when grown in the open. It is soft, with a white ring of sapwood about one to two inches in thickness. The heartwood is a clear yellow color or a yellowish-brown to a pale brown tinged with red. It has a pitchy, resinous odor and taste. It is rather light in weight, and only of moderate strength, although somewhat stronger than western yellow pine or Engelmann spruce. Poles of lodgepole pine, cut green and seasoned, are stronger than those of western red cedar for equal sizes, both in cross bending and in compression parallel and perpendicular to the grain. It is not durable when in contact with the soil, and all poles, posts, railroad ties, etc., should be treated before using.

The wood is easily worked, and takes paints well. Carefully manufactured stock resembles white pine, and it has a characteristic silvery sheen. Lodgepole pine lumber is often mixed with western yellow pine or white pine, being very difficult to distinguish between either of these species. Properly seasoned material does not shrink excessively, nor does it warp nor check, and is well adapted for box shooks. The holding power of nails in both the end grain and side grain is considerably greater than for either western yellow pine or western white pine.

At present the wood is used mainly for mining timbers, poles, railroad ties, posts, farm timbers and cordwood. It is used to some extent for general lumber purposes, box shooks, lath, flooring, and finish. Small quantities are also used for car construction, vehicle parts, coffins and caskets. Lodgepole pine is well adapted to the manufacture for pulp for newsprint by the sulphite process, but the presence of pitch has proved objectionable from the standpoint of pulp by the ground wood process.

Insects and fire are serious factors in the life of lodgepole pine forests. The mountain pine beetle (*Dendroctonus monticalae*) causes heavy losses annually, and wipes out large areas of standing timber in one attack. This is a brownish beetle about one-fourth inch long, which works between the bark and the wood, killing the trees by tunnelling galleries in the inner bark, thereby girdling the tree and cutting off the food supply.

Fires are usually fatal to the trees because the thin bark affords practically no protection.

Fungi are not of serious importance as a rule, although numerous species attack lodgepole pine to a limited extent. The most common are the ring-scale fungus, and the velvet-top fungus. The former chiefly attacks the older trees, entering where dead limbs or wounds afford openings for entry of the spores. This fungus causes a heart rot, ex-

tending both upward and downward from the point of entry. The velvet-top fungus causes a heart rot in the butt of the trees, rarely extending above the second log. This butt rot, also extending down into the roots, is one of the main causes of windthrow of lodgepole pine.

Sitka Spruce
(Picea sitchensis)

OF the seven species of spruce found in the United States, Sitka spruce, *Picea sitchensis,* occurring only along the northwest coast, is by far the most striking and attains the largest size. It is also a tree of great commercial importance. Other species which are of great value are the red and white spruces in the east, and the Engelman spruce in the Rocky Mountains and in the eastern portions of British Columbia, Washington and Oregon.

Sitka spruce, also called tideland spruce, is essentially a tree of the lower altitudes and moist situations. Botanically it is found along the Pacific coast of North America along a narrow strip of shore line from about 60 degrees North latitude (Cook Inlet) in Alaska, extending southward along the coasts of Alaska, British Columbia, Washington and Oregon to its southern limit near Casper, in Mendocino County, California, at about 40 degrees North latitude. Its greatest distance from the coast is nowhere more than 200 miles, the strip narrowing as its northern and southern limits are approached. As an individual tree its altitudinal range extends from sea level to about 3,000 feet in elevation.

Commercially Sitka spruce forests occur from southeastern Alaska to Coos Bay, Oregon, though by no means is spruce predominant, nor is it present everywhere. The heaviest stands occur in the northwestern part of the Olympic peninsula, and the Grays Harbor region in Washington, and the northwestern part of Oregon. As a tree of commercial importance. it rarely is found at an altitude over 1200 feet above sea-level.

There is estimated to be a total stand of about forty billion board feet of Sitka spruce, of which Alaska has 15 to 18 billion feet, British Columbia, 15 billion; Washington, 6 billion; and Oregon, about 4 billion feet. It forms only $1\frac{1}{2}$ per cent of the total merchantable stand west of the Cascades in Oregon and Washington; 6.7 per cent of the total coast timber in British Columbia, and 20 per cent of the coastal forests of southeastern Alaska.

The annual cut of spruce in Oregon, Washington, and British Columbia forms only about 7 per cent of the total lumber production, in California about 2 per cent, while in Alaska it comprises practically the entire cut. The annual lumber production is estimated at about 500 million board feet.

Sitka spruce is found in both pure and mixed stands, the latter type predominating. In Alaska and northern British Columbia it covers the greatest areas; as a rule, however, western hemlock will be found as an associating species. Further south other species are found, such as Douglas fir,

"Sitka Spruce: Its Uses, Growth and Management," by N. Leroy Cary, United States Department of Agriculture. Bulletin No. 1600.

BARK DETAIL, NEEDLES AND CONES, SITKA SPRUCE
—Photo by U. S. Forest Service.

western red cedar, silver fir, and lowland white fir, while at its southern limits of its commercial range the redwood and Port Orford cedar are found. Along the valley bottoms it occurs with broadleaf maple, black cottonwood, and red alder.

Characteristics

Sitka spruce attains the largest size of any of the spruces in the world.

It grows to a size comparable with the maximum of Douglas fir and red cedar, and larger than its other associates except the redwood. Individual specimens have been found attaining the heights up to 296, 285, and 282 feet; many have been found measuring over 10 feet in diameter. The largest one recorded measured 16 feet in diameter at 4½ feet above the ground. Trees scaling as high as 40,000 board feet of merchantable lumber have been found, but the average tree scales 5,000 to 8,000 board feet.

In Oregon and Washington average mature trees are about 200 feet tall and from 3½ to 4½ feet in diameter. In Alaska spruce is somewhat smaller, averaging about 150 feet in height and about 3 feet in diameter. The maximum age recorded for Sitka spruce is about 750 years. The average age of the old growth trees however is well under this, probably not more than 450 to 500 years.

Sitka spruce belongs to the conifer family, which is distinguished by the needle-like leaves. Its bark is very distinctive, making this species comparatively easy to distinguish from its associates. It is very thin, rarely over one inch in thickness, forming stiff, cupped, and eliptical, dark, purplish-gray scales, one or two inches in diameter. The needles, especially on younger trees, are stiff and bristly to the touch, sharply-pointed, and stand straight out in all directions around the twigs. They are somewhat flattened, only indistinctly four-angled, and about one inch long.

The cones are about 3 inches long, light brown in color, eliptical in shape and hang down conspicuously from the upper branches. They mature their seeds in one season. Due to the lightness of the seed kernel and the comparatively large wings, they are carried long distances by the wind.

The root system is very shallow, this being especially true of trees on swampy soils where the roots spread out very close to the surface. However, in deep, porous soils they penetrate four to five feet into the ground and occasionally considerably deeper.

Sitka spruce timber usually occupies two classes of sites—the bottomland and the slope. The bottomland type, being situated at the lower elevations with the best soils and greatest precipitation, contains the trees of largest diameter. In many cases these are comparatively short and with heavy limbs. The trees of the slope type, while not attaining the large size, are tall and straight with a good clear length. The wood is usually finer-grained, with fewer knots, resulting in a much greater percentage of the higher grades of lumber.

Reproduction

The perpetuation of Sitka spruce forests depends to a large extent upon the opening up of the stand sufficiently for the seedlings to survive. The method of logging in the coast region, technically called clearcutting, results in conditions which are favorable to the starting of a new crop. The main requisite, however, is that slash fires are kept from running over the cut-over lands, since no species can perpetuate itself when forced to combat the ever-recurring slash fires.

All spruce growth starts from seed, good seed crops being produced at intervals of three to four years. Moisture, light, and heat are essential to the germination and survival of these spruce seedlings, and in this regard the cut-over areas in the coast region offer very favorable conditions. Under ordinary conditions spruce seedlings are able to maintain them-

selves, and sometimes even form a greater percentage than was found in the original stand.

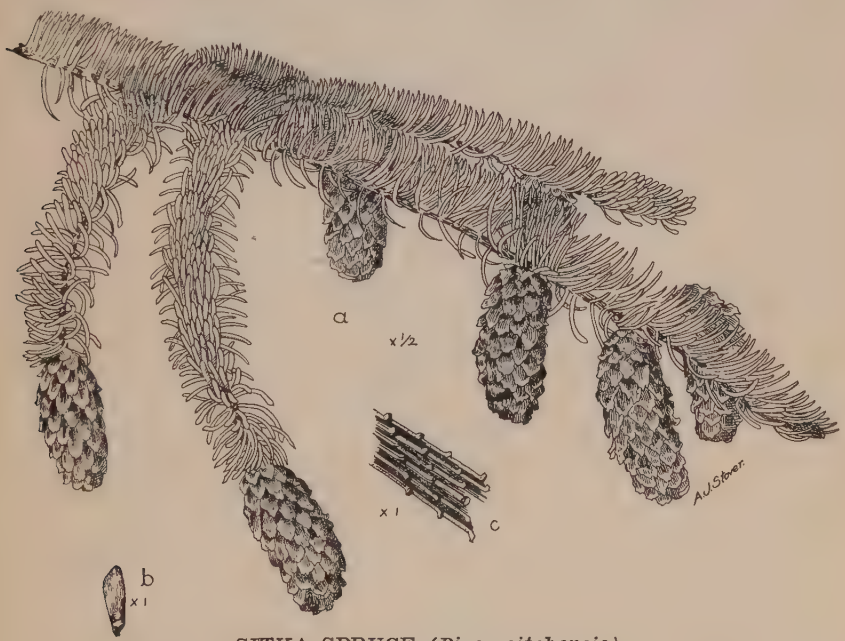
Growth and Yield

Measurements by the U. S. Forest Service show that Sitka spruce is a very rapid growing species capable of attaining enormous yields at maturity. Old growth stands have been found with volumes of 200,000 to 300,000 board feet per acre over considerable areas. Second-growth stands, at 100 years of age, fully stocked, have been found to average about 100,000 board feet per acre on the better sites—growing at the rate of 1000 board feet per acre per year. Trees at that age will average about 25 inches in diameter and 155 feet in height.

Properties and Uses

The wood of Sitka spruce is light weight, soft, straight-grained, tough, easily worked and comparatively strong for its weight. It is tasteless and contains very little resin. The color of the heartwood is a pale brown, blending into the creamy white of the sapwood. There is no distinct line of demarcation between the springwood and the summerwood.

The biggest part of Sitka spruce is manufactured into lumber. However, due to certain special qualities, spruce has found great favor as a specialty wood—principal of these being aircraft material, musical instruments, boxes, ladderstock, crates, veneer, woodenware, etc. About 40 per



SITKA SPRUCE *(Picea sitchensis)*

a. Fruiting branch showing pendant cones and leaves standing out from all portions of the stem.
b. Winged seed.
c. Detail featuring persistent woody leaf base.
(*x* indicates scale of reduction)
—Photo Courtesy Oregon State Board of Forestry.

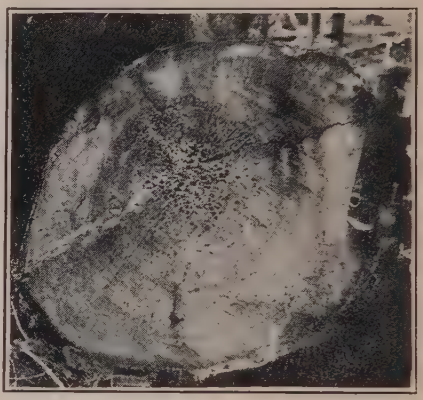
cent of the lumber is used for construction purposes, being suitable where great strength is not a requisite. It is especially desirable for large doors, beveled siding, and car stock. Large quantities are used for the planing mill industries, being used to advantage for doors, window and door frames, and moulding. Also, since it is tasteless, Sitka spruce is used extensively for containers in which food is packed or handled. It is not durable in contact with the soil or when exposed to the weather.

Sitka spruce is one of the leading woods for pulp manufacture by either the mechanical or chemical processes. It is soft, white, nonresinous, and its fibres are long and flexible. It compares very favorably with the white spruce, long used as a standard for pulp making in the United States, and all tests indicate that there is no difference between these two species for this purpose by either process.

Enemies

Sitka spruce is not seriously subject to damage, except through fire and wind. Up to reaching maturity it is scarcely affected by decay or insects, and only in a minor way through parasitic fungi upon the twigs and needles do these affect the growth of the trees. There are three fungus diseases in this class—the broom-forming rust, *(Peridermium coloradense),* causing pronounced "witches-broom," which ordinarily is not serious; the second is the needle-rust fungus *(Peridermium decolorans),* and is usually limited to attacking trees in the sapling and small pole sizes; the third is a needle browning fungus *(Lophodermium macrosporum).* None of these diseases causes sufficient damage so as to completely kill the young trees.

Other fungi causing damage to the wood of the living trees are the conk rot, or ring-scale fungus (*Trametes pini*), the butt-rot fungus (*Polyporus schweinitzii*), and the red-belt fungus (*Fomes pinicola*). Of these the ring-scale fungus is the most destructive, causing the common red rot or conk rot in the heartwood of living trees. The attack may be at any point along



CONK ROT IN SITKA SPRUCE

the trunk of the tree. This fungus gains entrance to the heartwood principally through old branch stubs, and is exceedingly destructive in mature and over-mature stands.

The next most important is the butt-rot fungus, found mainly in the roots and the butt of the tree. It is rarely found above the first log. Besides the actual loss due to the decay, a considerable amount of windthrow is caused due to the weakening of the tree at the roots and the butt.

Disease caused by fungi is very rare in trees under 100 years of age, and only a slight amount between 150 and 300 years. Beyond this latter age, however, both the conk rot and the butt rot are very common, taking as high as 25 per cent of the volume of the stand.

Insect damage to standing spruce

timber ordinarily is not very great. There are two classes of insects attacking this species, the bark beetles and leaf defoliators.

The most important is the bark beetle (*Dendroctonus obesus*), which attacks the living trees and kills them by girdling in the cambium layer or the inner bark. No extensive attacks have been found in standing spruce timber, although in the great Olympic Blowdown area, due to the excessive amount of down timber, reports have been received that an epidemic attack by bark beetles is imminent.

Defoliator attacks have been noted from time to time in northwestern Oregon and other spruce areas. These are caused by caterpillars and the larvae of the sawfly. As a rule these attacks are of limited duration, lasting only a few years, due to control by natural agencies, such as birds and other insects which prey upon the defoliators. The damage is caused by the stripping of the needles, usually resulting in the death of the tree.

Felled timber is subject to attacks by wood-boring insects in the nature of small round holes about the size of a pencil lead. These are ambrosia beetles, sometimes called pinhole borers. These may bore into the wood to a depth of from four to six inches, thereby seriously reducing the value of the clear sapwood, especially when it is being used for airplane stock. Logs placed in the water are usually free from this damage.

Wind is a very serious enemy of Sitka spruce. This is because spruce is a very shallow-rooted tree and because it grows close to the coast where excessive wind storms are subject to occur. Spruce trees which have grown in dense stands are rarely wind-resistant, and the leaving of scattered trees for seeding purposes on cut-over areas is rarely desirable because of their liability to windthrow.

Fire is a serious enemy because of the thin bark and exposed root systems of spruce trees. This species is, however, fortunate in having its habitat in a region where there is less fire hazard than usual, due to the low humidity, heavy fogs, cool temperatures, and moist ground conditions. However, during the short dry seasons, conditions may become extremely hazardous, and big fires have oc- in the spruce forests in the past, as is evidenced by the big "burns" in the Coast Range mountains.

As an individual tree spruce is very susceptible to fire, but as a forest spruce timber is not to be considered as a very hazardous fire risk, although adequate fire protection and care in the woods is always an essential requirement for the perpetuation of the forests of this species.

Englemann Spruce
(Picea engelmanii)

ENGELMANN spruce is one of the most important timber trees occurring at the higher elevations in western United States and Canada. It occurs in the Rocky mountains from the northern boundary of British Columbia to southern New Mexico, and in the Cascade range and Blue mountains of Oregon and Washington. It grows in rather moist situations, where the precipitation either in the form of rain or snow is comparatively heavy. Its altitudinal range is mainly from about 7000 to 12,000 feet in the southern Rockies, from 6000 to 12,000 feet in Utah and Colorado; in Idaho and Montana it is found as low as 2000 feet and as high as 11,000 feet. In Oregon and Washington it occurs from about 3000 to 7000 feet, and in British Columbia usually from 2500 to 6000 feet. These variations in altitude are due to range of latitude, and local variations of climatic factors. The higher elevations in New Mexico and Arizona are under about the same climatic conditions as the lower ones in Washington and British Columbia.

The present stand is estimated at about 77 billion board feet of timber, of which about 56 billion feet is in the province of British Columbia. The annual cut is about one billion feet, mostly in British Columbia, Idaho, Montana and Colorado.

Tree Description.

Engelmann spruce is very similar to the Sitka spruce of the Pacific coast, although differing sufficiently to be classed as a separate species. The foliage is deep blue-green, sometimes especially in young trees with a decidedly silvery or whitish tinge. The needles are four-angled, moderately stiff and bluntly soft-pointed to the touch, as contrasted to the very stiff and sharp-pointed needles of Sitka spruce. They are about one inch long, but often longer, especially on young, vigorous trees. A decided pungent ordor is emitted when young needles are crushed between the fingers. The cones mature in one season, and are from about one to three inches long, with an average length of about one and one-half inches. Sitka spruce cones are larger, usually about three inches long.

COMPARATIVE SIZES OF SITKA SPRUCE CONE (LEFT) AND ENGELMANN SPRUCE CONE (RIGHT).
—Photo by U. S. Forest Service.

When grown in dense stands it forms a straight, somewhat slightly tapering bole, which is fairly well pruned of its lower limbs. However, due to the durability of the dead limbs only a small portion of these drop off, so that only a small percentage of clear logs are obtained. The mature trees are usually about

*The Management of Engelmann Spruce by W. C. Lowermilk, U. S. Forest Service, District 1, Missoula, Mont., 1922.

100 feet in height and from 18 to 36 inches in diameter. Exceptional trees upon the better sites in Oregon and Washington have been found up to four and one-half or five feet in diameter and well up to 150 or 160 feet in height. The bark is thin and scaly, rarely over one-half inch thick; on older trees it is dark purplish-brown or russet-red, and composed of very loosely attached scales.

Habits and Growth

Engelmann spruce forms dense, pure stands over large areas in the regions of its best development, viz., British Columbia, Idaho, western Montana, and Colorado. Usually, however, it is found in mixture with other species; at the higher elevations with alpine fir, and white-bark pine; lower down with Douglas fir, lodgepole pine, western larch, western hemlock, western white pine, and white fir. On the east slope of the Cascades in Washington its chief associates are silver fir, noble fir, alpine fir, white fir, western larch, alpine larch, mountain hemlock and Alaska cedar.

Engelmann spruce is a tree that will grow upon most soils within its range where there is sufficient moisture. On the drier sites Douglas fir and lodgepole pine are able to crowd it out. It attains its best development in the deep soils of river bottoms and gulches where it has an abundance of soil moisture, and where it is not crowded out by other moisture-loving species. It can endure dense shade in youth, which characteristic enables the spruce to form an understory in the mature forest, and is then able to take advantage of any additional light through the dying out or windthrow of the older timber. Upon admittance of this top light, this understory responds readily and quickly shoots up to fill up the vacancy in the crown canopy. It is usual for trees which have been suppressed for 40 or 50 years to recover and form a new stand when the old trees drop out.

The best stands of Engelmann spruce are in British Columbia at elevations of from 3500 to 5000 feet, at the higher limits of commercial tree growth in the Cascades of Oregon and Washington, and in northern Idaho. In these regions mature trees on the average will run from about 24 to 40 inches in diameter and 120 to 130 feet in height. In the southern and central Rockies, where extensive stands occur, the average trees are somewhat smaller, from 20 to 30 inches in diameter and about 80 to 90 feet in height. Pure stands will yield about 5000 to 15,000 board feet per acre, although stands of 25,000 to 30,000 board feet per acre are not uncommon.

Engelmann spruce is a comparatively slow growing species, due to the rather short growing season and to the high altitudes under which it exists. In the Rockies it becomes merchantable at about 12 inches in diameter, then being about 125 to 150 years of age. On the better sites in the Cascades in eastern Oregon and Washington trees of this age will be about 16 to 20 inches in diameter on the average.

Reproduction and Management

Engelmann spruce reproduces from seed only, as far as the growing of commercial timber is concerned. However, at times at the higher elevations, it is one of the few conifers that reproduce by "layering," under forest conditions. This happens very rarely, and only in the moister situations where the lower branches come

into contact with the soil and take root, at the same time sending up shoots which form into individual trees.

Seed crops occur at about three to four-year intervals, and an abundance of seed is usually produced. Some seed, in small quantities, is produced even in the "off" years of production. The seeds are winged, light, and are capable of being distributed at considerable distances by the wind. In the closed forest, seeds take hold readily in the shade, and persist as suppressed seedlings for many years. These rapidly recover when there is an opening in the forest canopy and take the places of the older trees that have died out or have been windthrown. In this manner Engelmann spruce eventually crowds out the less tolerant species as Douglas fir, lodgepole pine and western larch.

On burned and cutover lands the matter of spruce regeneration presents more of a problem. The removal of the mature forest interrupts the natural course of plant succession, and offers different effects upon the various topographic exposures. On the southerly exposures lodgepole pine takes hold most readily, and will form the succeeding crop; although in time the spruce will make re-entry with other more tolerant species, and gradually replace the lodgepole. On the northerly exposures, the spruce and other tolerant species will follow immediately. This leads to the point that upon the drier southerly exposures a selection method of cutting, where sufficient trees are left to maintain a fairly close canopy, should be practiced; on the other hand, on the northerly exposures a clear cutting method may be used. From studies conducted in the northern Rockies, the following conclusions have been drawn:

(1) Engelmann spruce reproduction on cutover lands is dependent upon seed crops at the time of, or following cutting. It will not arise from seed deposited in the duff layer.

(2) Mineral soil surfaces favor the establishment of spruce seedlings by a ratio of 20 to 1 over that on duff surfaces.

(3) Reproduction on burned spots is not as numerous as on mineral soil.

(4) The conservation of the surface soil moisture throughout the critical dry period is the essential requirement to the establishment of Engelmann spruce reproduction.

The Wood

The wood of Engelmann spruce is light in weight, pale yellow in color, ordinarily close and straight-grained, even-textured, soft, easily worked, and not very strong. It shows no distinctly marked spring and summer wood, as do the pines and Douglas fir, and the heartwood and sapwood are so nearly the same color that it is difficult to distinguish between them. Because of its weakness it is not adapted to structural uses, but it is well suited to all purposes where neither excessive strength, hardness, nor durability are essential requirements. The lumber must be seasoned slowly to avoid checking or warping. The principal uses are for boards, dimension, boxes, ties, poles, mine timbers, posts and pulp. The wood has no odor and almost no pitch. It is especially suited for pulpwood; other specialty uses to which it is adapted are flour and sugar bins, bread boards, butter boxes, or any use where the odor of wood is objectionable.

Engelmann spruce can be ground for pulp the same as the white spruce

in the east, or the Sitka spruce of the Pacific coast. It produces a pulp with an excellent color with a long, strong fiber. It is also well suited for pulping by any of the chemical processes. Both ground and chemical pulp are equally as good as that produced from the eastern spruce as regards strength, cleanliness and other qualities.

Enemies

Due to its thin bark and its low-hanging, highly inflammable limbs, Engelmann spruce is easily killed by fire. Thus, the spruce is sometimes wiped out of a stand where the thicker barked, fire-resistant trees as Douglas fir, western larch, and white fir are able to persist. Even though the spruce is not killed outright, light ground fires cause fire scars which provide entrance places for fungi, causing butt rot and heart rot. The principal fungi attacking Engelmann spruce are the ringscale fungus, *Trametes pini,* the velvet-top fungus, *Polyporus schweinitzii,* the two root fungi, *Poria subacida* and *Fomes annosus.* In addition two rusts are found, the spruce cone rust, *Melampsoropsis pyrolae,* and the spruce rust, *Melampsorella elatina.* These two rusts are not of very great importance.

Western Red Cedar
(Thuja plicata)

THE western red cedar of the Pacific Northwest is quite a distinct species from the red cedars of the east and from any others of the western cedars. Botanically, the western red cedar is related to only one other species in the United States, this being the eastern white cedar (*Thuja occidentalis*), found as a comparatively small tree in the moister situations of northeastern United States and the adjacent Canadian provinces. The western red cedar, by contrast, is a very large tree growing in the northwestern states of Washington, Oregon, Idaho, the province of British Columbia and the territory of Alaska.

Other red cedars, growing in the eastern and southern states, are of the juniper family, having, however, the characteristic red wood whereby they have been known as "red cedars" for many years before the western red cedar was discovered. These belong to the genus *Juniperus.* The other western cedars, as Port Orford cedar, Alaska cedar, and incense cedar are also distinct from the western red cedar in that neither of them is botanically related to it; the two former belonging to the genus *Chamaecyparis,* and the incense cedar belonging to the genus *Libocedrus.*

Western red cedar is found in the moister situations of the Pacific Northwest, from the southeastern coast of Alaska to northern California; also eastward through southeastern British Columbia and northern Washington into northern Idaho and Montana; and eastward into the Cascade range of Washington and Oregon. It is found chiefly in regions of fairly high precipitation, and confined to situations which are quite wet or constantly moist. It is a tree suited mainly to the lower altitudes, rarely occurring commercially above 3500 feet elevation, except in

the Rocky mountain regions of Idaho, Montana and British Columbia.

Red cedar rarely occurs in pure stands, usually occurring as a component of the mixed Pacific Coast forests consisting of Douglas fir, western hemlock, silver fir and Sitka spruce. It rarely forms more than 50 per cent of the stand over any considerable area. Further eastward, into northern Washington, it is found with Douglas fir, western larch, white fir and Engelmann spruce, while in Idaho it is found with western white pine, western hemlock, white fir and larch.

Characteristics

Western red cedar has a decidedly tapering trunk with a characteristically "swell-butted" base. Very old trees are conspicuously swell-butted, and have a typical fluting at the base extending upward from 10 to 20 feet. The bark, even in old trees, is very thin, usually one-half to three-fourths inch, and rarely over one inch in thickness, and peels off easily in long thin strips. It was used for basket making by the Indians in the early days.

The needles are small and scale-like with a dark green color. They in no manner resemble the needles of Douglas fir, spruce, hemlock, nor any of the pines—but are quite distinctive from them. Mainly they are similar to those of the incense, Port Orford, and Alaska cedars in being rather flattened, jointed and short. The cones are rather small, usually about one-half inch long, which ripen their seed in one season.

As an individual tree western red cedar attains a very large size. Trees measuring 16 feet in diameter and with a height up to 250 feet have been found; however, the average old growth timber ranges from about three feet to eight feet in diameter and from 150 to 200 feet in height. As a rule these large trees are very swell-butted with hollow trunks and broken tops. Many are also spike-topped with long spike-like bare tips sticking upward into the sky. Second-growth trees, in situations suited to this species, make fairly good growth, at 80 years of age attaining a diameter of 19 inches and a height of 100 feet. On less favorable sites, such as the poorer soils and steeper slopes, it takes a cedar from 100 to 150 years to attain this size.

Red cedar trees attain a very old age, specimens of this species being found well over 1000 years old.

Reproduction

Western red cedar reproduces itself entirely from seed. Good seed years occur at intervals of three to four years, although some seed is borne almost every year. The seed is light and small, and is carried long distances by the wind. It requires considerable moisture for germination and the establishment of the seedlings, reproducing best where protection is accorded from direct sunlight and drying winds. It comes up fairly well on cut-over lands where cedar was found in the original stand, and will be probably grown best in mixed stands with which it naturally occurs, namely: Douglas fir, hemlock, spruce and the balsam firs.

The Wood

The wood of red cedar is of soft texture, light in weight, usually straight-grained, and with a rather coarse even grain. The sapwood is narrow, usually one to one and one-half inches, almost pure white, while the heartwood varies from a light yellow to a dark reddish brown. The wood has a characteristic aromatic odor and is free from pitch or resin.

WESTERN RED CEDAR
—Photo Courtesy Oregon State Board of Forestry.

It is much lighter and weaker than Douglas fir; in these respects it is similar to Sitka spruce, although it is more brash. It is adapted to uses requiring durability rather than strength.

The principal uses to which red cedar is put are poles, shingles and

lumber. It is the standard pole timber in the west; these poles being obtained principally from the north Puget Sound region, northeastern Washington, and northern Idaho where the greatest amount of suitable sizes are found. These are used extensively for telephone and telegraph poles, and transmission lines all over the country, usually in the round form after peeling. Cedar is also used to some extent as piling, although not so extensively as Douglas fir for this purpose. Its principal merits for these uses are its form, lightness and durability.

A considerable amount of western red cedar is made into split posts, for which it is well adapted because of its ease of splitting, lightness and durability. These are used mostly by farmers and transportation companies for fencing purposes.

Western red cedar is manufactured into various forms of sawn products, of which clear lumber is a highly developed specialty. Due to loose knots its use for lumber is generally restricted to higher grades, which has to be absolutely clear stock. Thus, the inferior portions of the logs are usually transferred to the shingle mills, leaving only the best quality for lumber manufacture. From these better portions are cut large quantities of clear bevel siding, which is the most valuable lumber product manufactured. In addition to siding, red cedar is cut into shop and common lumber, car siding and roofing, ceiling, tank stock, porch columns, mouldings, lath, and interior finish. Bevel siding and finish comprise about 90 per cent of the total lumber product.

Shingles of the western red cedar are produced in far greater quantities than shingles of any other species. The greater portion of these, by far, is manufactured in the state of Washington. Shingles are made from both logs and bolts—these latter being logs cut into short lengths, usually 52 inches long, and split into sections for ease of handling. Shingles are made in various lengths, as 16-inch, 18-inch and 24-inch usually, although sometimes cut as long as 36 inches. Shingles are used both for roofing purposes and siding.

There is estimated to be a total stand of about 80,000,000,000 board feet of western red cedar in the United States, of which Washington has about 55,000,000,000 board feet, Oregon 20,000,000,000, and Idaho and Montana 5,000,000,000 feet. In addition, British Columbia has approximately 75,000,000,000 board feet of red cedar timber, or about 22 per cent of the total timber stand in that province, while Alaska has about 3,500,000,000. This makes a grand total of some 158,500,000,000 board feet of western red cedar in the Pacific Northwest.

The annual cut for all classes of products, such as lumber, shingles, lath, poles, piling, posts, etc., for the Northwest amounts to about 1,500,000,000 board feet, of which by far the greater portion is manufactured into shingles. Thus, in British Columbia, 60 to 70 per cent of the total cedar timber is made into shingles, while in Washington and Oregon shingles form about 75 per cent of the total manufactured output. In Idaho and Montana, the principal product cut is the pole.

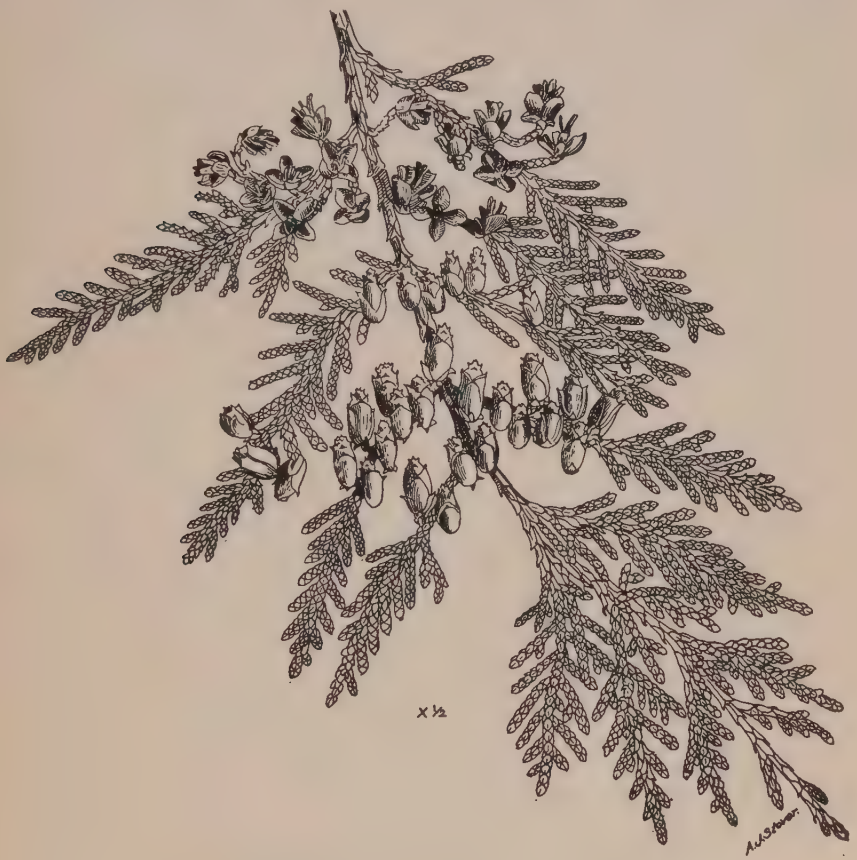
Enemies

Western red cedar, as an individual tree, due to its thin bark and shallow root system, is easily damaged or killed by fire. However, due to its growing usually in moist situations

this risk is somewhat lessened; but in spite of this fire is the most serious enemy to the perpetuation of the forests of red cedar.

Cedar has few insect enemies, and thrifty trees are seldom attacked by them. This may be due to the strong aromatic character of the wood which may be disagreeable to most insects. In some localities a flat-headed borer, called the western red cedar heartwood borer, does much damage to living trees by tunneling through the wood. These tunnels are from one-fourth to one-half inch in diameter. The term "wormy cedar" is applied to timber damaged by this borer. Two borers, of little importance, do some damage; these being the cedar bark borer which attacks recently felled trees, and the cedar tree borer working in dead or injured trees.

Red cedar suffers little from fung-



WESTERN RED CEDAR *(Thuja plicata)*

a. Fruiting branch showing scale-like overlapping leaves with resin pocket on outermost portion of each leaf, old persistent cone with reflexed scales and also newly matured cones. Each cone has its individual stem. Note the resemblance of cones to "Dutchman's Pipes".

—Photo Courtesy Oregon State Board of Forestry.

ous diseases until after maturity, when butt rot and heart rot cause much damage. Practically all large, overmature cedar suffers from these causes, resulting in a great loss of valuable material and hollow-butted trees which are easily subject to windthrow.

Port Orford Cedar
(Chamaecyparis lawsoniana)

THE genus *Chamaecyparis,* commonly known as cedar, consists of three species in the United States. One is in the east, known as white cedar *Chamaecyparis thyoides,* and two are in the west. These western species are the Port Orford cedar, *Chamaecyparis lawsoniana,* and the Alaska cedar, *Chamaecyparis nootkatensis.* These three cedars are in some respects similar to the western red cedar, although differing considerably in others.

Port Orford cedar is the most important of these two western species from a commercial standpoint at the present time. This species is confined solely to the coast region and the lower foothills of the Siskiyou mountains in southwestern Oregon and northwestern California. As a commercial tree its range is very limited. The best timber is found in Coos and Curry counties in Oregon, ordinarily not over 40 miles or so from the coast line. Bodies of commercial value extend southward in a very narrow belt for some distance south of the Klamath river in California. Scattering individuals and small groups occur eastward to the southern slopes of Mount Shasta and up the Rogue river and its tributaries close in towards Grants Pass. Its altitudinal range is from practically sea level up to about 5000 feet elevation.

Tree Description

In a mixed forest, such as where it usually occurs, Port Orford cedar stands out conspicuously from its associates. The bark is silvery brown in color, ridged and broken, and quite thick at the lower portions of old trees, sometimes six to eight inches. It is divided into deep narrow seams, and in the nature of rather loose ridges which separate into long strips. The base of the older trees is usually buttressed and irregular in form, which, with the narrow and compact crown, makes the tree distinctive from the other species. The foliage presents a graceful feathery appearance of a yellow-green color; the tip and the extremities of the leading branches have a characteristic droop. The leaves are small and scale-like, on flat sprays, and soft to the touch, being in direct contrast to the prickly feeling of the leaves of Alaska cedar. The points of the leaves are shorter and blunter than those of western red cedar, incense cedar, or Alaska cedar. The cones are small and round, about one-fourth to three-eighths inches in diameter, of a dark russet brown color when ripe. They ripen their seed in two seasons, in constrast to the red and incense cedars which ripen their seed in one season.

Habits

Port Orford cedar is primarily a moisture loving tree, although it will grow in regions of dry soils and low atmospheric moisture. However, it requires an abundance of soil and atmospheric moisture to thrive best. It grows most abundantly along watercourses and protected north

slopes and benches. Its principal associates in its commercial range are Douglas fir, Sitka spruce, western red cedar, lowland white fir, and western hemlock in Oregon; in California it is found usually with lowland white fir, western hemlock, Sitka spruce, and occasionally redwood and Douglas fir. On the relatively dry sites it is sometimes found in the yellow pine-sugar pine forests. In very few instances does Port Orford cedar form pure stands, and then only of very limited area. In the Coos Bay region it forms from about 10 to 25 per cent of the stand; oftentimes in other parts of its range it occurs only in small groups or single trees, forming usually less than 10 per cent of any considerable forest area.

Reproduction and Growth

The growing of a new crop of Port Orford cedar is a matter largely tied up with adequate fire protection. Without this young trees can not exist. The seed will germinate equally well on burned or unburned areas; but repeated fires running over cut-over lands result in complete destruction of young growth. Seed crops are fairly frequent and heavy, the seed is fairly light and will carry long distances in moderately strong winds. Young growth will persist both in the open and in moderately shady places, indicating that either clear cutting or the selection systems are applicable in removing the old stand. Dense shade, however, is detrimental, and eventually results in stagnation and death of the tree.

Individual trees attain a large size, averaging from three to five feet in diameter and 150 to 180 feet in height. Exceptional specimens have been found with a diameter of seven to eight feet and over 200 feet in height. This species lives to a considerable age, no doubt well over 500 years. Young trees, growing where full sunlight is available, as in even-aged stands, attain a fairly rapid growth. However, growth is somewhat slower than either for Douglas fir, Sitka spruce, or western hemlock under the same conditions. Measurements are to a large extent lacking, however, one set showing an average diameter of 24 inches at 100 years and 35 inches at 150 years is indicative of what may be expected.

The Wood

The wood of Port Orford cedar is of exceptionally high value. It is light in weight, very fine grained, of a faint yellowish-white color tinged with red. It has a distinct faint aromatic odor; it is rather hard and firm, works easily, and is very durable. The large trees yield a high per cent of clear lumber, and a specialty is made of grades suitable for interior finish. A large proportion of Port Orford cedar is shipped to Japan in the log or in squares where it is used for house construction. The wood is resistant to both decay and to insects. It is also used for battery separators, general interior finish, boat construction, pattern stock, sash and door stock, tunnel work, railroad ties, furniture, chests, drawers, etc.

Alaska Cedar
(Chamaecyparis nootkatensis)

ALASKA CEDAR, also known as yellow cedar, yellow cypress and Alaska cypress, is a little known species of the north Pacific coast. It is found along the coast and islands of southeastern Alaska and British Columbia, southward through Washington into northern Oregon. North of Vancouver Island it occurs at sea level to 3000 feet elevation; in the Cascades of Washington and Oregon, on both sides, it occurs from 2500 to 7000 feet. Within its range it is sometimes confused with western red cedar; however, the finer character of its foliage, its smaller and rounder cones, and the yellowish and harder wood makes these two species fairly easily distinguishable.

Range and Distribution

Alaska cedar occurs over a very wide range, although at the present time it is one of the non-commercial species in the region. However, the character of the wood and its abundance, and the undoubted scarcity of other species in the future, will no doubt bring it forward as one of the important specialty woods of the coast. The principal forests, suitable for commercial timber, are situated in northern Washington, on the west slopes of the Cascades and in the Olympic mountains. Here it occurs in pure stands and in mixture with other species, the former at times covering quite extensive areas. Its associating species are principally western hemlock, lowland white fir, western red cedar, yew and silver fir at the lower limits of its range; higher up it is found with mountain hemlock, alpine fir, silver fir, noble fir, white pine, larch and Englemann spruce. Trees of merchantable size are usually along moister situations, or in regions of high precipitation and high humidity.

Trees of this species attain a fairly large size at times, old trees up to four or five feet not being uncommon. Ordinarily in maturity it is from two to three feet in diameter and 75 to 100 feet in height. Forest grown trees are clear of limbs from 35 to 50 feet; the trunk is rapidly tapering from a buttressed base, which is always more or less fluted. The bark is very thin, rarely over one-half inch in thickness, affording but poor protection against fire. It is ashy brown on the outside, reddish cinnamon brown where broken. The leaves are compressed, blue-green in color, noticeably harsh and prickly to the touch, in this latter respect unlike the smooth sprays of the western red cedar. The cones take two seasons to ripen the seed, they are a deep russet-brown color, round, and about one-half inch in diameter.

The Wood

The wood of Alaska cedar is not used to any appreciable extent at the present time, due mainly to the relative inaccessibility of this species. It is exceedingly fine-grained, because of the slow growth, and is a comparatively hard and heavy wood for a cedar. It is firm, splits quite readily, and is very durable when exposed to the weather, earth or water. Logs of this species have lain on moist ground for years without any signs of decay. It is bright sulphur-yellow in color, even-grained, finishes readily, and takes paints and stains very well. Its use is rather limited now, but it is

well adapted to furniture manufacture and cabinet work, interior finish, boat material, and sash and door stock. Principally it has been used for boat building, to which it is well adapted because it is practically unaffected by changes in moisture conditions, and is less liable to shrink, warp or check than most other species used for this purpose.

Little is known of the silvicultural habits of this species. Seedlings appear to grow both in the open and in part shade. As with other species, constantly recurring fires are damaging to the perpetuation of the young growth, and also do damage to the older trees in the way of butt fire scars and death due to the thin bark. Ordinarily little decay is noted on trees which have not reached overmaturity.

Incense Cedar
(Libocedrus decurrens)

INCENSE cedar, *Libocedrus decurrens,* the only species of the genus *Lobocedrus* in the United States, is found in the Pacific coast region only in the states of Oregon and California. Two other related species, very important trees in their range, are found in western South America. In the early geologic ages other species of this genus existed in Greenland and in portions of Europe. These latter are now, however, extinct.

Tree Description

Incense cedar is characterized by its rapidly tapering form, its buttressed trunk, its shreddy deeply furrowed yellowish brown or cinnamon colored bark, and the dark green foliage. Old trees have a bark from two to three inches thick, sometimes six to eight inches thick; on younger trees it is flaky, more or less tinged with red, showing a lighter yellowish under bark where it has scaled off. The crown in early life is typically conical, becoming later more open and irregular, often deformed by witches broom and mistletoe. The foliage is evergreen, of a dark green color, consisting of small pointed scale-like leaves adhering closely to the branchlets. These leaves are characterized by long bases, about one-fourth to three-eights inches long, by which this cedar may be easily distinguished from the other cedars in this region. The cones are pendulous, and rather large for a cedar, about three-fourths to one and one-half inches long, and three-eighths inches thick. They consist of three pairs of scales, which upon opening extend outward from the base.

Habits and Growth

The range of incense cedar is limited to the mountainous regions of southern Oregon and California, extending southward into Lower California in Mexico. In Oregon it is found in the southern Cascades and the Siskiyou mountains, extending eastward into the timbered regions in the Warner mountains in the vicinity of Goose lake. Its northern limits are in the North Santiam headwaters and its tributaries. It is found rather sparingly in this state, nowhere occupying the ground as a forest type to any considerable extent. In California it is more common, both in the Coast range and the Sierra Nevada, being of greatest abundance in the northern coast mountains and in the

Mount Shasta region. The altitudinal range in Oregon is between 2500 and 5000 feet in the western portion, and from 4500 to 6000 feet east of the Cascades. In California its limits vary from 1000 feet in the southern part of the Coast range to as high as 9000 feet in the southern part of its range. It attains its best growth between 3000 and 6000 feet in the regions of heavy precipitation and abundant atmospheric moisture.

The estimated available stand of incense cedar is about eleven billion board feet, of which about ten billion board feet are in California. It is found only in mixture with other species, principally western yellow pine, sugar pine, Douglas fir, white fir, western red cedar and hemlock in Oregon; in northern California with sugar pine, yellow pine, Jeffrey pine, white fir and bigtree; in its southern limits chiefly with sugar and yellow pines, and sparingly with white fir and hardwoods at the lower elevations.

Incense cedar is found upon a great variety of soils and sites, but it has its best growth and development as a forest type upon the cooler and moister soils where there is abundant atmospheric moisture. Here it can maintain itself to best advantage in competition with other species. Its occurrence on the dry sites is due to its ability to endure them, the growth on such sites being exceedingly slow and the trees stunted.

In general the growth of this species is rather slow when compared to that of competing trees. This is mainly due to it growing mostly as an understory beneath the main forest canopy. It reproduces quite abundantly and can exist in the densest shade, although too much shade hinders growth and development. Reproduction is from seed only, good crops occurring generally at periods of about once in every three years, although some seed is produced annually. Seedlings occurring under the main stand make a very slow growth, taking between 25 and 30 years to attain an average height of three feet. The greatest height growth occurs between 50 and 75 years of age. At 100 years of age the average heights will range between 50 and 80 feet; diameters will run from 12 to 20 inches. At 200 years trees will average about 90 to 110 feet tall and 24 to 30 inches in diameter. Individual specimens have been found up to five or six feet in diameter and 150 feet in height. Even under best conditions of growth incense cedar can not compete with its principal associates, sugar pine and yellow pine.

The Wood

From a commercial standpoint incense cedar lumber is comparatively little known in the general market. At present it is cut only incidentally with other species, and the lumber usually is mixed with one or another of these. Locally in California it is used to a considerable extent, mostly for rough lumber, and a lesser amount for ties, pencil slats, posts, poles and stubs, firewood, shingles and shakes. Sound trees make excellent lumber, it being light, soft and easily worked. Due, however, to the prevalence of "dry rot" or "peckiness" the cull will sometimes run to as high as 40 or 50 per cent of the total tree volume. Sound, clear lumber has been used for pattern stock and cabinet work, commanding good prices for these purposes; however, there is only a small amount of this class of stock produced from the average tree. Mainly, in the general market, the lumber is used for building purposes, such as outside trim and

interior finish. The aromatic odor of the wood, from which it derives its name, makes it desirable for chests and wardrobes, supposedly being mothproof. Locally most of the lumber is used for dimension and rough construction work, bridge planking, etc., where cheapness and durability are important.

The principal defect in incense cedar is the dry rot or peckiness caused by the dry rot fungus, *Polyporus amarus*. Other diseases of little commercial importance are a mistletoe and a rust fungus. The dry rot fungus attacks the heartwood of living, mature trees only; those under about 140 years being immune usually. Fire scars and branch stubs are the main sources of entry of this fungus to the heartwood. The wood is honeycombed with cavities from one-fourth to one inch in size and up to several feet in length. These cavities are filled with a dry brown charcoal-like substance, from which this rot obtains its name. Insects rarely kill incense cedar, except in the seedling and sapling stage. Mature trees succumb only after repeated attacks, while young trees are usually killed outright in one season.

Repeated ground fires are the cause of considerable damage, both in a primary and a contributory manner. Practically no mature trees are found without fire scars; these scars are a constant source of weakness against fungus attack. Reproduction suffers severely from fires, as no matter how light the fire the small seedlings are destroyed, and no future stand can be expected where repeated fires are allowed to run through the woods.

EXCELLENT STAND OF YOUNG WESTERN YELLOW PINE UNDER MATURE TIMBER

Western Larch
(Larix occidentalis)

THE larches*, also called tamaracks, are widely distributed over the northern and mountainous regions of the world. Species are found in northern Asia, northern Europe, and in the northern portions of North America, nine species in all being recognized. In the United States and Canada there are three species—namely the eastern larch, or tamarack, *Larix laricina;* occurring mainly in the eastern portions of these two countries, although also extending westward and north into northeastern British Columbia and into Yukon territory; the western larch, *Larix occidentalis,* found in northwestern United States in the northern Rocky Mountains and the Cascade Range, and extending into southern British Columbia; and the alpine larch, *Larix lyallii,* a high mountain species in the northern Rocky Mountains and in the Cascade Range of the United States and southern British Columbia and Alberta. Of these species the eastern larch, or tamarack, and the western larch are commercially important.

Tree Description

The principal distinguishing features of the larches are the numerous short leaves, from about 12 to 30 or 40, in clusters on short spur-like branchlets, and the habit of the leaves to drop off each autumn during the months of September and October. This latter characteristic is unique among the coniferous, or the so-called "evergreen" species.

The western larch, sometimes also called tamarack, is the giant of the larches, attaining a height up to about 200 feet and a diameter between five and six feet. Ordinarily trees are from about 150 to 180 feet tall and from 2½ to 4½ feet in diameter. The trunks are quite tapering, and clear of branches well up into the tops. The crowns are very narrow and pyramid-like, rather short, and running up into a slender point. They are usually quite open with the branches covered sparsely with the leaves.

The leaves are from about one inch to nearly two inches long, and grow in clusters of from about 14 to 30. In the spring they are a light green color, presenting a marked contrast against the dark green foliage of the other conifers in the forest which retain their leaves throughout the winter. Toward fall these leaves begin to drop, and by late fall the trees are entirely shed of them. The cones mature, or ripen, their seed in one season, and are from about one inch to 1½ inches long, with long pointed extruding bracts. The bark on old trees is exceptionally thick, from three to five or six inches, and is deeply furrowed, with a reddish cinnamon-brown color. It acts as an excellent protection against ground and surface fires. On young trees the bark is much thinner, from one to 1½ inches, rather scaley, and dark or grayish-brown in color.

Range and Distribution

Western larch is found usually in the higher valleys and upon the moun-

*In the Pacific Northwest the name "larch" has been applied by lumbermen to trees of the genus *Abies*, principally to noble fir *(A. nobilis)* and silver fir, *A. amabilis.* These two species are in no way related to the larches, and calling them such leads to confusion.

PURE LARCH STAND ON UPPER YAAK RIVER IN KOOTENAI NATIONAL FOREST, MONTANA
—Photo by K. D. Swan, Courtesy U. S. Forest Service.

tainous slopes of southeastern British Columbia, northwestern Montana, northern Idaho, eastern Washington and northeastern Oregon. Its principal commercial range is in eastern Washington, northern Idaho, western Montana and northeastern Oregon. Associated species occurring

with larch are mainly Douglas fir, white fir, lodgepole pine, western yellow (pondosa) pine, and Engelmann spruce in Washington and Oregon; in Idaho its associates are western (Idaho) white pine, western red cedar, western hemlock, Douglas fir, Engelmann spruce and white fir. It is sometimes found in pure stands exclusive of other species, but usually it occurs in mixed stands. It is found growing upon the cooler and moister north and west exposures where it can obtain a maximum of soil moisture and the cooler temperatures. It thrives best on deep, fresh, porous soils but will grow on shallow moist soils and in gravelly dry soils.

Reproduction

Seed production of western larch is very abundant as a rule, with some seed produced each year; however, it is locally variable in its abundance. The seed is relatively small and light in weight, has a fairly high rate of germination, and moderately persistent vitality. Usually a great portion of the seed is shed upon the snow. Abundant soil moisture is required for the germination and ultimate survival of seedlings. The young growth is very intolerant of shade, and requires considerable top-light for development and best growth, and can not persist for any length of time in the forest in the shade of the older trees.

The most serious competitor of larch is lodgepole pine, seedlings of both species being partial to burned-over areas with exposed mineral soil. On such areas the character of the reproduction depends upon whether the larch or lodgepole pine seeds in first; if the pine gets the start it will shade out the more intolerant larch. The thin foliage of the larch cannot prevent other species, such as the pine, Douglas fir, white fir, or spruce from getting a start, and as a result pure larch forests are not very common, and mixed stands with some or all of the above species are found where larch occurs at all.

Habits and Growth.

Even in old age, as in early life, western larch is a light-demanding tree, probably even more so than the western yellow (pondosa) pine. For its best development, as for its germination and early survival, it requires full top light; however, this disadvantage of intolerance toward shade is partly overcome by its early rapid height growth, allowing it to surpass its more tolerant competitors. As an individual tree western larch attains a large size; its straight, smooth, slightly tapering trunk with a comparatively small, sparse, open crown is very characteristic; the bole tapering gradually to a sharp spire-like point. It grows to a very old age, trees up to about 700 years of age having been found. However, in the average mature forest it is usually between 250 and 400 years of age, with a diameter of from 2½ to four feet, and 150 to 180 feet tall.

From the standpoint of future forest production western larch growth varies greatly within its commercial range. Measurements taken in a larch-Douglas fir stand in Montana show that it takes approximately 150 years to produce a tree 100 feet tall with a volume of 150 board feet; in the Blue mountains in Oregon its rate of growth is about the same. On the better sites in both regions growth is more rapid, and trees averaging about 16 inches in diameter and about 250 board feet are obtained in about 100 to 110 years.

The yield of larch stands is variable, depending upon its manner of

origin and the physical, topographic, and climatic factors. Pure larch forests are not very common, since larch usually occurs in mixture with other species. The present mature stands are considerably understocked as a rule, and show a much smaller volume than can be obtained in the future under forestry practice. These present stands contain from about 5000 board feet to 15,000 or 20,000 board feet per acre; indications are that fully stocked second-growth stands of larch will contain about double, or even triple this volume.

Management

Western larch at the present time, except perhaps in Montana, is being cut very sparingly, and only in the best of stands where the choice trees are taken out in connection with western yellow pine cutting operations. However, as the yellow pine timber becomes scarcer larch will naturally replace it to some extent, and more extensive operations will result in large areas of this species being cut. Since it is better adapted than other species to certain kinds of forest land east of the Cascade Range and in the Rocky Mountains, foresters will desire to perpetuate it wherever it is possible to do so to advantage.

The management, or cutting operations, of western larch in order to obtain future crops, will be based upon the inability of this species to perpetuate itself under the old stand, and to its adaptation and rapid growth upon the moister sites. These sites will always be favorable to larch timber, and the manner of cutting should be such so as to favor the natural regeneration of this species upon them. As the intolerance of larch young growth precludes its survival under the old trees, and since it can not compete successfully with lodgepole pine upon recently burned over areas, a system of clear cutting with the absence of broadcast burning will no doubt be best suited for obtaining future growth. This is especially desirable upon the poorer sites, where lodgepole pine usually stocks up a burned over area to the exclusion of other species. In this connection seed for natural stocking will have to be provided for by leaving seed trees on the cut-over areas, either singly, in groups, or in strips; or the cutting area will have to be left small enough so that seed will blow onto it from the adjacent standing timber. Since the seed is very small and light, and seed crops fairly frequent and abundant, the number of seed trees will not need to be excessive, perhaps not more than 3 per cent of the volume, unless it be desired to leave a greater number for increased growth and value, to be logged at some future time after the area has restocked and before maturity of the next crop. Areas restocked in this manner will no doubt contain other species in mixture, such as Douglas fir, white fir, Engelmann spruce, lodgepole pine, and perhaps some yellow pine. On such cutting areas the percentage of lodgepole pine, be it so desired, may no doubt be kept to a minimum by cutting out all the trees of this species in the logging operations.

The Wood

The greater proportion of the cut of western larch is from the states of Idaho and Montana. Since it is usually marketed with Douglas fir it is very difficult to obtain accurate figures on the amounts cut and the distribution of its products. The total lumber production is between 350 million and 400 million board feet annually, of which Oregon produces

about 5 per cent, Washington 20 per cent, Montana 35 per cent and Idaho 40 per cent.

The wood of western larch is clear reddish-brown, heavy, and fine-grained as a rule; it is quite durable. In this latter respect it differs greatly from the eastern larch, or tamarack. It is also a comparatively hard and heavy wood for a conifer. In an air-dry state it weighs about 36 pounds per cubic foot; or, one-inch lumber, surfaced two sides, weighs about 2400 pounds per 1000 board feet. Larch slivers quite easily and has a tendency to raise the grain, resulting in a corrugated or "washboard" surface. It ranks third in strength among the western conifers, only Douglas fir and western hemlock being superior in this respect. It averages about 80 per cent of the strength of Douglas fir, the strongest conifer in the west.

Western larch is used mainly for structural purposes, to which it is well adapted in obtaining large tree sizes, and in strength. Vertical grain material makes excellent flooring on account of its hardness, high polish, and fine texture. It is also used for finish lumber to some extent, to which it is well adapted through its excellent figuring, but the small proportion of this material obtained from the tree limits its use for this purpose. Its fine texture, easy working, and its ability to take stains, varnishes, and oils make it particularly well suited for ceiling, wainscoting, door and window casings, baseboards, etc. For exterior uses it is also of high value due to its durability, strength, and its ability to take varnishes and paints. It is used for car roofing, outside flooring, doors, porches, columns, pergolas, siding, steps, sash, etc., as it withstands weathering very well. Other uses are for tank and silo stock, wood-blocks for paving, telegraph pole cross arms, flumes, culverts, railroad ties, trestle timbers, bridges, wharves, and general construction work.

Enemies

The principal enemies to western larch growth are fires, fungi and insects, of which the latter is perhaps the least important.

Fire is mainly detrimental in the complete destruction of young growth, which due to its thin bark and inflammable crowns, is unable to resist this scourge. Old stands, with their thick bark, are able usually to withstand complete destruction, but even then considerable damage results in the way of fire-scarred butts through which fungi are later able to enter, thereby ultimately causing great damage and even destruction as a secondary enemy.

Fungous diseases cause considerable damage to older stands of larch timber, rarely, however, being found in timber still in the thrifty second-growth stage. There are three such diseases found, namely the quinine fungus, *Fomes laricis,* the ring scale fungus, *Trametes pini,* and the velvet top fungus, *Polyporus schweinitzii.*

Of the above diseases the most damage is done by the *quinine fungus.* This causes a decay in the heartwood of the tree, and is not confined to any particular portion of the bole. It causes a crumbly brown, brittle, and dry rot. It makes its entry into the tree and the heartwood through the dead branches and stubs.

The *ring scale fungus* causing red heart or red ring rot is also found throughout the bole of the tree, the decayed portions showing as small white pits in the wood. The fruiting portions issue outward through the knots, causing the typical swelling or

"conks" which indicate this fungus.

The third fungus, the *velvet top fungus,* causes the typical butt, or stump rot. This rot rarely extends more than eight to ten feet above the ground, mostly not more than five or six feet upward. It is indicated by conks at the base of the tree or on the ground near the tree. Decay enters through wounds, mainly fire-scars, at the base of trees; investigations show that the greater portion of fire-scarred trees have butt rot. This rot also enters through the roots to some extent.

Western larch, as a rule, is not especially subject to attacks by insects. In the east, where the tamarack is found, heavy damage has resulted from the larch saw-fly, which work in the leaves of the trees, and gradually strip them off. In the west only one such attack has been noted, namely in 1920 and 1921 in northern Idaho and northwestern Montana. This resulted in no permanent damage, however, since the attack was not repeated and the attacked trees recovered shortly afterward. There have been no other insect infestations recorded in western larch timber anywhere in the northwest within its range.

Considerable damage is caused to larch trees by mistletoe, in both old and young timber. This is typical "witches broom" seen in the crowns of the trees, also causing swellings on the boles. In neither case does death result directly, but growth is materially lessened, thereby lowering the vitality of the trees so that they become easier prey to disease.

The Balsam Firs
(Genus abies)

THERE are ten species of the balsams, or true firs, distinguished in the United States, two in the east and eight in the west.

The two eastern species are generally knows as balsam firs, the more important one, *Abies balsamea,* occurring in northeastern United States, eastern Canada, and Newfoundland westward to Lesser Slave lake, northern Michigan, and Minnesota. The other eastern balsam, *Abies fraseri,* is found in the Applachian mountains from southwestern Virginia to western Carolina and eastern Tennessee. Neither of these balsams attains any considerable size, rarely over 2½ feet in diameter and not more than 70 or 80 feet in height. The prominent resin blisters on the bark of these two species no doubt gave them their name "balsams," and from them is obtained the liquid resin which is noted for its healing qualities.

The western species* found variously throughout the Rocky mountain and Pacific coast regions of the western United States and Canada are the silver fir, *A. amablis,* lowland white fir, *A. grandis,* noble fir, *A. nobilis,* red fir, *A. magnifica,* Shasta red fir, *A. magnifica shastensis,* white fir, *A. concolor,* alpine fir, *A. lasiocarpa,* and bristlecone fir, *A. venusta.* Variously some one species of this genus is found from sea level to the upper limits of tree growth.

Of these western balsams the noble fir, silver fir, white fir, red fir, and

*Lumbermen have generally in the past designated these firs as "larch," and as such much of the lumber has been marketed.

Shasta red fir are of commercial importance.

Noble Fir

Abies nobilis

Noble fir, known usually in the lumber trade as "larch," while being the most valuable of the balsams from the standpoint of the wood, is the one which is most limited in extent of forest area and in quantity.

It is found principally along both sides of the Cascade range in Oregon and Washington, extending from about the Diamond lake region in Oregon northward to the vicinity of Mount Baker in northern Washington. It has also been found to a very limited extent in the Coast range in Oregon. Its commercial range may be said to be limited to the northern part of Oregon and the southern part of Washington in the Cascade range.

The total estimated stand is between three and four billion feet, board measure, of which about one-half is within the Mount Hood, Santiam, Columbia and Rainier National forests. The best commercial stands, mostly cut over now, were in the vicinity of Larch mountain, Oregon, about 30 miles east of Portland.

Generally, noble fir occurs in mixed stands at an elevation of from about 3000 feet to 4500 feet upon the moister slopes and benches. The species in mixture vary with the altitude and the latitude; in Washington usually being Douglas fir, western red cedar, western hemlock, white pine, silver fir and alpine fir. Further southward it occurs with white fir, white pine, sugar pine, western hemlock and alpine fir. Its botanical range extends to as low as 2000 feet elevation at its northern limits, and up to about 5000 feet elevation toward its southern limits.

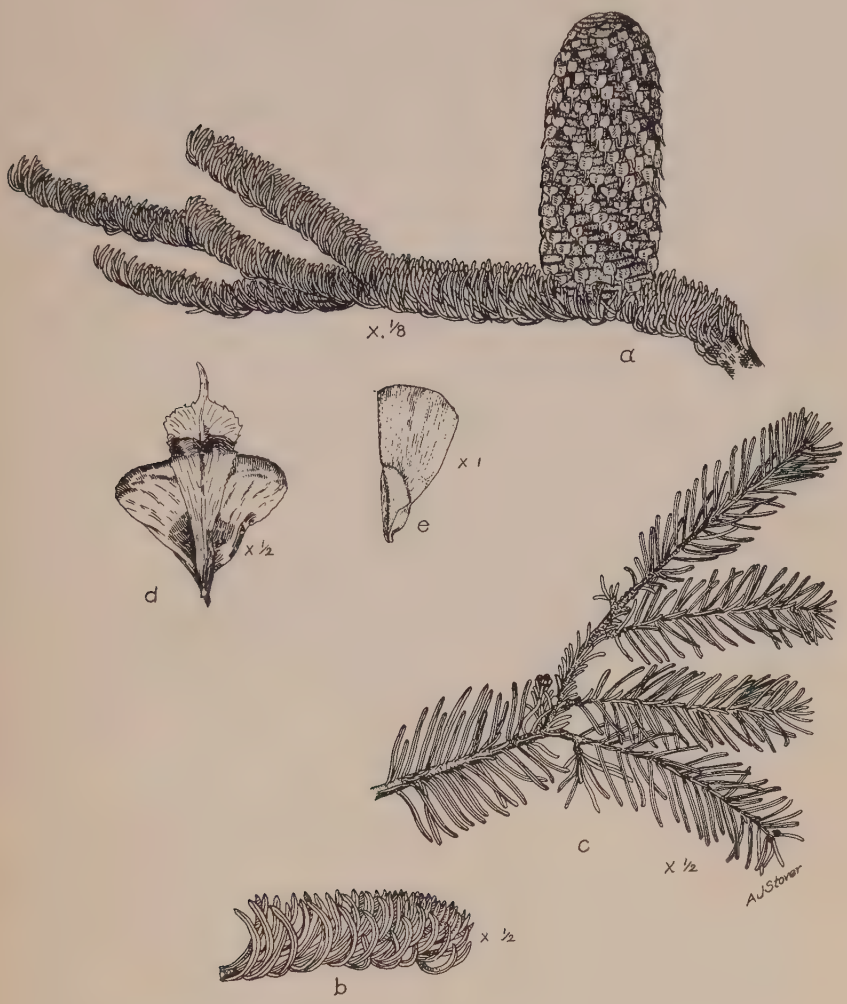
Tree Description

Noble fir forms a tall, straight tree, with a full cylindrical bole and a comparatively small open crown in its mature stage. Old trees have been found up to six feet in diameter and a maximum height of about 215 feet; the average mature tree will run about $2\frac{1}{2}$ feet to four feet in diameter and from 150 to 180 feet tall. The bark of mature trees is comparatively thin, $1\frac{1}{4}$ to $1\frac{3}{4}$ inches thick, purplish in color, and divided by narrow seams into flat, narrow ridges. In younger trees the crown extends well down towards the ground, the bark is of grayish color, thin and flat, with conspicuous resin blisters. These blisters, however, are also characteristic of the young trees of the other balsams.

The leaves occur singly, without a distinct petiole, or stem, and are turned upward so as to appear to grow from the top sides of the branches. They are usually four-angled, especially on the upper branches; those of the lower crown are more commonly flat. The leaves of the upper crown are sharp-pointed, less than one inch in length; the lower needles are usually notched at the tip, and about one to $1\frac{1}{4}$ inches long. The upper surface of the needles is usually a dark green, the under side is a silvery color due to the presence of numerous stomata, or spores.

The cones are very distinctive. Similar to the other balsams, they stand upright, but they differ from them in that the extruding sharply-pointed bracts completely cover the outer surface of the cone. They are from $4\frac{1}{2}$ to seven inches long and $2\frac{3}{4}$ to 3 inches thick; usually about twice as long as thick, with rather straight sides. When the seeds ripen the cone begins to break up and the cone-scales

†Preliminary Growth and Volume Study of Noble Fir, University of Washington Forest Club Annual; Vol. III, 1915, by E. J. Hanzlik.



NOBLE FIR *(Abies nobilis)*

a. Fruiting branch showing erect mature cone with extended bracts.

b. Detail featuring arrangement of leaves particularly uppermost twigs; also found on small specimens.

c. Arrangement of leaves occasionally found on lower branches of crown and also observed in small juvenile specimens.

d. Lower side of cone scale showing irregularly notched bract with long tapering point.

e. Winged seed, natural size.

(*x* indicates scale of reduction)

—Photo Courtesy Oregon State Board of Forestry.

drop to the ground, leaving a straight spike pointing upward in the tree crowns.

Growth and Yield

Noble fir attains a fairly rapid growth in both diameter and height, which is comparable to that of competing species under the same physi-

LOOKING UPWARD INTO CROWNS OF NOBLE FIR, OLD GROWTH TIMBER, LARCH MOUNTAIN, OREGON.
—Photo by Author.

cal and climatic conditions. A study conducted in the vicinity of Larch mountain, Oregon, at about 3000 feet elevation, in a mixed stand of Douglas fir, western hemlock, and noble fir showed approximately the same diameter growth for all species; at 120 years of age, which is about the rotation period for these species, the diameter at breast-height (4½ feet above ground, outside bark) was 23½ inches and the total height of 110 feet. No data are available to give yields of second-growth stands, but indications are that noble fir will approximate the yields of second-growth Douglas fir under similar conditions of site and climate.

Reproduction

New growth of noble fir starts only from seed, which requires considerable overhead light for best development and survival. It is the most intolerant, or light-demanding, species of the balsams. Seed will germinate either upon bare mineral soil or duff, but reproduction takes place only in openings, such as caused by windthrow or fires. At the lower elevations, in mixture with Douglas fir and western hemlock, it is probably best adapted to clear-cutting with scatterd seed trees, or by seeding in from the side; at its upper limits, where the timber is of especially great value from the standpoint of watershed protection, some system of cutting in groups will probably give most satisfactory results. Due to the excellence of the wood, its rapidity of growth, and general adaptability to certain sites in the upper slope region, noble fir should be one of the favored species for perpetuation within its commercial range.

The Wood

The wood of noble fir is light brown in color, it is odorless, free from pitch and resin, splits readily, and is easily worked. It is rather heavy and fairly strong, being one of the heaviest and strongest of the balsams. Large mature trees in heavy stands contain a comparatively high proportion of clear, straight-grained lumber due to the lower limbs dying and dropping off at a fairly early age. In both strength and weight it is about midway between Sitka spruce and Douglas fir. The better grades of lumber are used for interior finish, siding, flooring, and sash and door stock. Considerable amounts have

also been used for car siding and boxes. Its comparative lightness, freedom from pitch and odor, and softness, make it well suited for box manufacture. These same qualities no doubt in the future should make it one of the desirable species for the manufacture of wood pulp.

Enemies

Due to its thin bark noble fir is easily damaged or killed by fire; however, because of its general occurence upon the moister sites in regions of greater humidity this factor is usually not of exceptionally great importance. Disease in the younger stands is not very common; only in the older trees is there any great loss due to decay caused by fungi. As with the other balsams the greatest loss is the stringy brown rot, a decay caused by the Indian paint fungus, *Echinodontium tinctorum*. Losses due to other decays are the butt rot, or dry brown rot, caused by the velvet top fungus, *Polyporus schwienitzii*, and a heart rot caused by the sulphur fungus, *Polyporus sulphureus*.

Insect damage is practically unknown in noble fir.

Silver Fir

Abies amabilis

Silver fir reaches its best development as a forest type and as an individual tree along the lower west and south slopes of the Olympic mountains, the west slopes of the Cascade range in Washington, and the foothills of the lower Columbia river region in Oregon and Washington. Botanically its range extends southward from southern Alaska in the Coast mountains and both sides of the Cascade range through British Columbia, Washington, and Oregon down to the vicinity of Crater lake. Only in Alaska and British Columbia does it reach sea level; ordinarily its altitudinal range is between about 1000 feet and 5000 feet in elevation; however, occasional trees or stands of limited area are found well up to 6000 feet in exceptional instances. The bulk of the possibly commercially accessible silver fir timber is estimated to be about 50 billion feet, board measure, of which about 35 billion feet are in Washington and northern Oregon, and the remainder mainly in British Columbia, with an almost

CONES OF SOME OF THE PRINCIPAL BALSAM FIRS
—Photo Courtesy U. S. Forest Service.

negligible quantity in Alaska. It covers considerable areas in pure stands, especially in the Olympic mountains and the northern Cascades where the volume will average from 40,000 to 50,000 board feet per acre; exceptional stands have been found over this figure. It also occurs in mixed stands, other species being Douglas fir, red cedar, western hemlock, Sitka spruce, and lowland white fir at the lower elevations; noble fir, western hemlock, lowland white fir, white pine, alpine fir, red fir, Engelmann spruce, western larch, and lodgepole pine at the higher elevations.

Tree Description

Younger silver fir trees are characteristically distinct with their thin, tight-appearing, smooth, ashy-gray, unbroken bark, conspicuously marked with large chalky-white areas. As the trees get older, the bark, although still comparatively thin, becomes seamed and breaks up into conspicuous flakes, especially toward the base, which drop off in time and accumulate on the ground. The needles occur singly and are usually one to one and one-half inches long, dark green on the upper sides and a silvery color underneath. They are flat, with a groove upon the upper surface, notched or bluntly pointed at the tip. They have a distinct short stem which has a characteristic twist thereby massing the needles upon the upper portions of the twigs, in contrast to the flat, two-ranked appearance of the lowland white fir which also has the needles attached to the twigs with a distinct short stem. The cones are erect, dark purple in color, about four to six inches long and $2\frac{1}{2}$ inches in thickness. The bracts, shorter than the cone scales, are rounded, gradually narrowing into a long slender point.

As an individual tree, silver fir occasionally attains a large size, trees under favorable conditions being found close to six feet in diameter and 200 feet tall. Mature trees in the forest are as a rule from two to four feet in diameter and about 150 to 160 feet tall. Due to the thin bark, rarely over $1\frac{1}{2}$ inches in thickness, and to the full cylindrical bole, silver fir trees contain a comparatively high volume.

Reproduction and Management

Regeneration of silver fir is entirely by seed. Due to its ability to endure shade, it can reproduce under the shade of the forest cover, although growth under these conditions is very slow. However, when the old trees are removed, the understory trees rapidly increase their growth in both height and diameter, thereby in a short period filling up an opening in the forest canopy. This suggests that some sort of a selection method of cutting is adapted to the perpetuation of this species. However, it has also been found that silver fir seedlings will take hold and thrive in the open wherever there is sufficient soil and atmospheric moisture, and that seed will germinate on both mineral soil and duff, thereby indicating that on certain sites a clear cutting system can also be used. Growth in these open areas naturally is much faster than under the shade of the older trees; the former will result in even-aged stands while the latter in all-aged (or uneven-aged) stands. The even-aged forests will no doubt produce the best timber in the shortest time and should be favored wherever the conditions are suitable for clear cutting.

Growth and yield data in detail

are lacking for this species; however, observations and cruises tend to indicate that under similar physical and climatic conditions silver fir will yield a volume comparable to that obtained by associating species.

The Wood

The wood is soft and light in weight, easy to work, is easily seasoned, is not brittle, nor does it splinter. It splits easily, is free from loose knots, does not check nor warp badly in seasoning, and has no excessive shrinkage. It is not adapted where strength, hardness or durability are required, but its suitability for boxes, interior finish, sash and door stock, and shiplap has been shown. In the past, the greater portion has been shipped mixed with Douglas fir, hemlock or spruce for interior finish and siding. It is also suitable for wood pulp and a considerable amount is used for this purpose from the lower Columbia river region. Very little of this species is now being cut for lumber purposes.

DENSE STAND OF SILVER FIR, OLYMPIC NATIONAL FOREST, WASHINGTON.

—Photo by Author.

As with noble fir, decay in silver fir is not found to any extent in trees until after they reach maturity, or over about 200 years of age. The principal rot is that due to the Indian paint fungus, *Echinodontium tinctorum,* causing a stringly brown rot in the heartwood of the tree. Other decays are of little practical importance.

White Fir

Abies concolor

Lowland White Fir

Abies grandis

THESE two species cover a very wide range of territory in western United States, one or the other of them being found in practically every state from the Pacific coast eastward to the Rocky mountains. Although classed as two distinct species by dendrologists, and being fairly easy to distinguish in their extreme forms, there are certain regions in which it is almost impossible to determine whether the specimen is the white fir, *A. concolor,* or lowland white fir, *A. grandis.* Such is the case especially in the Cascade range in southern Oregon where the rather more typical form from California, identified as *A. concolor* comes northward to meet the southern extremity of *A. grandis* from northern Oregon and Washington.

Generally it may be said that lowland white fir is found in the northern portions of the Pacific coast and Rocky mountain regions, namely in British Columbia, Idaho, Washington, Oregon, and the northern coast region of California; while white fir

is prevalent in the southern and eastern extremities, such as southern Oregon, California, southern Idaho, Nevada, Utah, Colorado, Arizona and New Mexico. The principal factor regarding the distribution of these species appears to be atmospheric moisture — lowland white fir being mainly a tree limited to the more humid Pacific coast and northern Rocky mountain regions, while white fir is more closely associated with the moisture situations in the more arid regions of the Sierras and the southwest in general.

Tree Description

The general characteristics of the two species are very much the same, except with specimens from the coast extremities of lowland white fir and the southern Rocky mountain form of white fir. Intermediate forms are commonly very difficult to distinguish, and as there is very little difference in the commercial qualities of the wood, which is only little used at the present time, the name "white fir" is usually appplied to either species.

As a distinguishing feature from the other commercial balsam firs, the needles of the white firs, on the lower branches particularly, present a flat, two-ranked appearance, appearing to grow and to stand out distinctly from two opposite sides of the stem. These needles are brought to this position by a decided twist at their bases where attached to the branches. These lower leaves are as a rule flat, grooved along the midrib, blunt, and distinctly notched at the tip. The upper crown needles present a decided contrast, the leaves being usually more crowded together and pointing upward, while those near the tips of the sprays are rather sharply pointed. The undersides of the needles of both species are conspicuously white. The upper surface of the needles of lowland white fir, the northern species, is generally a deep shiny green in the extreme lower coast region to a somewhat grayish green in the Cascade range and in the Blue mountains. On the other hand the upper surfaces of white fir are conspicuously white. The difference in color of the upper surfaces of the leaves is the prime distinction between these two species, this being due to the absence of stomata, or pores, in the lowland white fir and to their presence in white fir.

The bark of young trees of both species is very similar, being rather thin, grayish with a brownish tinge, quite commonly with blisters. Old trees represent a great contrast between individuals of lowland white fir, in that the low altitude trees have a comparatively thin bark, rarely over $1\frac{3}{4}$ inches thick, red-brown in color, hard, close, and broken into rather squarish checks. The bark of the higher altitude trees closely resembles that of white fir, being thicker, from three to four inches, conspicuously rough, with deep furrows and long ridges. The typical white fir bark in its principal range in California and the Rocky mountains is usually even thicker, from $4\frac{1}{2}$ to 6 inches, but maintaining the deeply furrowed characteristics. The cones of both species are upright before ripening, usually in the upper portions of the crown. They are from $3\frac{1}{2}$ to 5 inches long and $1\frac{1}{4}$ to $2\frac{1}{4}$ inches thick, yellowish-green to olive-green in color, sometimes purplish. The bracts attached to the cone-scales are shorter than the scales, with a small tooth-like point extending outward between sometimes heart-shaped and sometimes squarish shoulders. The cones of

LOWLAND WHITE FIR *(Abies grandis)*

a. Twig from top of tree showing erect cone and persistent axis of cone of previous year.

b. Twig showing flat spray of leaves characteristic of lower branches. Note notched leaves and blunt, resin-coaed winter buds.

c. Lower side of cone scale featuring bract distinctly notched, shoulders slightly rounded and with short tip.

d. Detached winged seed.

(*x* indicates scale of reduction)

—Photo Courtesy Oregon State Board of Forestry.

white fir are usually somewhat larger than those of the lowland white fir.

Habits and Growth

These species occur in both pure and mixed stands, although more commonly in mixture with other species. They ordinarily are found growing in the moister situations where they have an abundance of soil moisture. Both are very tolerant of shade, and young trees will persist for many years in the shade of the mature forest. Upon being opened up to top light, these trees recover very rapidly and form a new forest canopy in a comparatively short time. Lowland white fir, in the northern Rockies, northern Cascades, and the lowland coast region is found from sea level up to 7000 feet; its principal commercial limits being from about 500 to 5000 feet west of the Cascades and the coast of California, and from 3000 to 6000 feet east of the Cascades, in the Blue mountains and the Rocky mountains. Most commonly lowland white fir occurs in mixed stands; in the humid region of Washington and Oregon with Douglas fir, western hemlock, Sitka spruce, western red cedar, silver fir, red alder, maple and cottonwood. In the coast region of California redwood is an added associate. At the higher elevations in the Cassades other species are western larch, lodgepole pine, Engelmann spruce, Shasta red fir, alpine fir, noble fir, western white pine, and yellow pine. In the northern Rockies there is practically the same mixture, while in the Blue mountains in northeastern Oregon the principal associates are Douglas fir, western larch, lodgepole pine, and yellow pine. White fir is a tree found at the higher elevations, from 6000 to 11,000 feet in the Rocky mountains, and from 4000 to 8000 feet in the Sierra Nevada. Usually the commercial limits are from 7000 to 9000 feet in the former, and from 5000 to 7000 feet in the latter region.

The white firs are large trees, individual specimens being between 4 and 5 feet in diameter and well up to 200 feet in height. These maximum sizes are in the Pacific coast region; in the Rock mountain region however trees over three feet in diameter and over 120 feet in height are rare. The average commercial size in its optimum region is from two to four feet in diameter and from 140 to 160 feet in height.

The white firs reproduce from seed only, and as a rule the young growth is not very exacting except as to the moisture content of the soil. For good reproduction an abundance of soil moisture is required; young trees will grow either in the shade or open sunlight. For best growth however, about one-half shade is required in early life and full top light is essential after the seedlings have become well established.

The Wood

The wood of the white firs has been used to only a limited extent up to the present time. It is rather light and soft, but quite firm; moderately coarse-grained, and straight. It varies in color from a pale yellow to a light brown. It works easily, and takes a good finish. While not strong, it is well suited to general construction purposes where exceptional strength is not required. It is also adapted for siding, framing and general inside uses. Due to its light weight, straight grain, and ease of nailing the wood is well suited for box shooks. It has also been found to be a very desirable wood for the manufacture of pulp and paper.

Yield

The yields of white fir are comparable to those of other species growing under the same physical and climatic conditions. The best stands occur in the more humid regions of the Pacific coast, and the western slopes of the Cascade range and the Sierra Nevada. Fully stocked stands of second-growth timber have been found to contain an exceptionally high yield on the best sites such as are found in certain parts of northern California. The following table, based on measurements in fully stocked stands gives the yields of white fir lumber that may be expected to be obtained on different sites at different ages:

Yields Obtainable at Various Ages on Different Classes of Land in Northern California*

	SITE I (Best Land)			SITE III (Med. Land)			SITE V (Poor Land)		
Age, Years	Ave. Diam. Inches	Ave. Tot. Ht. Feet	Board Ft. Per Acre	Ave. Diam. Inches	Ave. Tot. Ht. Feet	Board Ft. Per Acre	Ave. Diam. Inches	Ave. Tot. Ht. Feet	Board Ft. Per Acre
60	15.6	100	81,500	13.1	80	52,600	9.0	50	9,200
80	18.6	114	122,000	15.6	92	82,200	10.9	58	21,100
100	20.8	122	147,800	17.2	98	100,700	11.9	62	29,000
120	22.3	127	163,800	18.3	102	113,100	12.7	64	33,900
140	23.5	130	176,700	19.1	104	121,800	13.2	65	37,500

Board foot volumes in the above table are according to the International ¼" Rule, corresponding very closely to the actual lumber tally obtained by using a saw cutting an ⅛" kerf and under ordinary careful sawing methods.

*Yield, Stand, and Volume Tables for White Fir in the California Pine Region, by F. X. Schumacher; Bulletin 407, University of California Agricultural Experiment Station, Berkeley, California.

The yields in the above table are for fully stocked stands and are what may be expected under the most favorable conditions of forestry practice. Average well-stocked stands will yield about 25 per cent under the figures as indicated above. In general Site I lands are those where the present dominant mature trees average over 175 feet in height; on Site III lands they are from 126 to 150 feet; on Site V from 76 to 100 feet.

Enemies

Old trees are very much subject to decay, due mainly to the Indian paint fungus, *Echinodontium tinctorum* causing a stringy brown rot in the heartwood. In southern Oregon and northern California about 75 per cent of the decay was found to be caused by this fungus.* It usually enters through the fire scars at the bases of the trees, never entering through the intact bark. With the control of fire by far the greatest danger from decay is eliminated. The thriftier trees, up to 125 or 130 years of age are rarely attacked, so that in the practice of forestry, when trees will be cut at about these ages, the factor of decay will have little effect. Considerable damage in standing timber in California and southern Oregon also results from a small bark beetle.

*Decay in White Fir (Abies concolor), Crater National Forest, Oregon. Ms. Report, Dr. E. P. Meinicke, Forest Pathologist, U. S. Department of Agriculture.

This beetle, a small scolytid, *Scolytus subscaber,* works in the soft cambium tissue in the inner bark between the bark and the wood, so that when the tree is attacked in sufficient numbers it is killed or weakened by being girdled. In eastern Oregon, eastern Washington, Idaho and Montana the lowland white fir is subject to attack by the eastern spruce budworm, *Harmologa fumiferana,* which

CONES AND FOLIAGE OF SHASTA RED FIR

results in the defoliation of the crowns. This insect work sometimes results in killing the trees outright, and sometimes only temporarily strips the leaves; in the latter case recovery takes place but with a slackening of the growth for a period of years.

The Other Balsams

The remaining commercial balsam firs are the red fir, *Abies magnifica,* and the Shasta red fir, *Abies magnifica shastensis,* two closely related species occurring in the Cascade range in southern Oregon and in the Sierra Nevada in California. The northern limits of these is in the vicinity of Crater and Diamond lakes, from there extending southward along the higher mountain slopes into the southern Sierras. They are usually found at the higher elevations, from about 5000 feet up to 9000 feet, generally where there is a mediumly heavy rainfall and heavy snows. These red firs occur either in pure or mixed stands, usually with yellow pine, sugar pine, Douglas fir, white fire, lodgepole pine, mountain hemlock and alpine fir. A rather moist, well-drained porous soil is preferred, although trees will grow upon dry and rocky sites.

Tree Description

Red and Shasta firs grow to a large size, from 3 to 4 feet in diameter and up to about 180 feet in height. The bark on old trees is rather thick, with deep ridges and a red-brown color. It is from 2 to 3 inches thick,

hard and rough, with the ridges divided by diagonal furrows, giving them a distintive zig-zag trend, quite distinct from the bark of any other species. Young trees have a smooth, chalky-white bark, which is quite thin.

The needles are distinctly 4-angled and sharply pointed, all appearing to grow as from the upper portions of the stems. They are without a distinct petiole and without a twist at their bases. The foliage is dense, of a dark green color, with a whitish tinge. The needles are from $\frac{5}{8}$ to $1\frac{1}{4}$ inches long, longer in the lower crown than towards the top. The cones stand upright, from 5 to 7 inches long and $2\frac{1}{2}$ to $3\frac{1}{2}$ inches in diameter. They are rather ovoid than cylindrical in shape. The distinctive feature between the red fir and the Shasta red fir lies in the extruding broad bracts that extend beyond the cone-scales in the Shasta fir, while they are completely hidden in the red fir. Otherwise it is practically impossible to distinguish these two species. The wood of these species is also very similar and no attempt is made to market it otherwise than simply "red fir." It is rather heavy for the balsams, is yellowish-brown with a reddish tinge. It is soft, but firm, rather brittle, straight and usually fine-grained, more durable and considerably stronger than the other balsams. Its firmness and good working qualities make it useful for a number of purposes to which pine is put, while the clear boles permit of a considerable quantity of clear lumber. It is an excellent boxwood, and should be well adapted for all general construction.

Other balsam firs, of no commercial importance, are the alpine fir, *Abies lasiocarpa,* and bristlecone fir, *Abies venusta.* Both are high mountain species, the former with a very wide range in Alaska and British Columbia southward into the Cascade range, the Blue mountains, and the Rocky mountains. Bristlecone fir is a rather rare species, little known, found only to a limited extent in the mountains of central California. Both species are very well suited for ornamental purposes because of their slow growth and excellent form. In some localities alpine fir has good possibilities as a commercial tree in the future, especially for the manufacture of wood-pulp, to which the white, soft wood is well suited. It also should make excellent box material.

Pacific Coast Hardwoods

THE hardwoods, or the broadleaf species, of the Pacific coast region are of very limited importance, both from the standpoint as forests and in the manufacturing field in the lumbering industry. However, certain features and changing economic conditions are bringing certain ones to a greater appreciation, and as a result more attention is being paid to them from the standpoint of their supply and utilization.

The most important Pacific coast hardwoods are red alder, *Alnus rubra,* bigleaf maple, *Acer macrophyllum,* black cottonwood, *Populus trichocarpa,* Oregon white oak, *Quercus garryana.* Other hardwoods of more limited range and of lesser value are western birch, tanbark oak, and Oregon ash. Species of a specialty nature, furnishing woods for novelty uses are the Oregon myrtle, Pacific dogwood and madrona. Of great importance from the medicinal standpoint is the cascara sagrada, or chittam wood.

Red Alder

Red alder, *Alnus rubra,* is the leading hardwood native to the Pacific coast region, both in point of supply and in use of the wood.

It is a tree of relatively small size, rarely over 30 inches in diameter, and with a maximum height of about 120 or 130 feet. Average forest grown trees in the region of its best development are from 14 to 18 inches in diameter and 80 to 100 feet tall. They attain maturity at a fairly early age, at about 50 or 60 years, and those living beyond 80 years are exceptional. The bark of red alder trees is very conspicuous by its ashy-gray or white color, which is spotted by characteristic dark blotches. It is quite thin, usually about one-half inch even on old trees. The bole, when grown under forest conditions, is straight and slender, giving off rather slim branches, which form a narrow, long, dome-like crown. It clears itself of limbs quite early in life, forming clear trunks for about 20 to 40 feet from the ground.

The growth of red alder timber is remarkably rapid, principally because it is found upon the better soils at the lower elevations, where there are an abundance of moisture and comparatively mild temperatures. A study conducted in the Puget Sound region showed that at 30 years of age trees averaged 11 inches in diameter outside the bark at 4½ feet above the ground, and were 82 feet tall; at 40 years they were 13 inches in diameter and 90 feet tall; at 60 years they had a diameter of 18½ inches and a height of 105 feet.* Well stocked stands of alder averaging 40 years of age were found to contain from 10,000 to 30,000 board feet per acre, or from 30 to 65 cords, indicating an average growth rate for the period of from one to 1½ cords an acre a year.

Range and Supply

Red alder is probably the most conspicuous hardwood of the Pacific coast region. It is found from southeastern Alaska to southern California, but its commercial range is limited to the moister lowlands of western portions of Oregon and Washington,

* Red alder of the Pacific Northwest, Bulletin No. 1437, U. S. Dept. of Agriculture.

and southwestern British Columbia. On the lower slopes of the coast mountains it is found in pure stands of fairly large extent, usually occupying the moister draws and slopes

TYPICAL ALDER BOARDS
The one on the left is practically "clear". The others show characteristic defects.
—Photo Courtesy of U. S. Forest Service.

having the western and northern exposures. In many instances alder is one of the first species to take possession of burned or cut-over lands which have been slow to reforest to coniferous species. It is also found in mixture with Douglas fir, western hemlock, western red cedar, Sitka spruce, white fir, and with other hardwoods, principally cottonwood and maple.

The merchantable supply of red alder in Washington and Oregon is estimated at slightly over one billion board feet, of which 750 million feet are in Oregon and 360 million feet in Washington. The area in Oregon bearing commercial stands, situated mainly within about 30 miles of the Pacific ocean, is about 75,000 acres; in Washington the area is about 30,000 acres, extending somewhat further inland than in Oregon.

The Wood

The wood of red alder shows no marked contrast between the heartwood and the sapwood, being nearly white and of high moisture content when freshly cut. Shortly afterward, however, it turns to a light reddish-brown, or sometimes to a light golden when cut in the fall of the year. The grain is straight and of uniform texture, the narrow bands of summer wood appearing only as fine lines in the radial section. The wood has no definite showy figuring. When properly handled red alder wood will not warp, check, shrink nor swell to any appreciable extent. It turns well and takes a fair polish. It also takes glue, paint and enamel well, and when stained it resembles mahogany or walnut. It is moderately light in weight, being lighter than any other western hardwood except black cottonwood. It is soft in texture, and is classed as moderately strong as compared to the eastern white oak. In comparison to competing woods which are put to the same uses, such as red gum, yellow poplar, basswood, etc., red alder has been found to be as desirable as any of them.

Uses

Red alder wood is used mainly in the secondary wood-using industries in the states of Oregon and Washington. The greatest portion of it goes into the manufacture of furniture. Out of a total cut of about 13½ million board feet reported in

ALDER STOOLS AND ROCKING CHAIR

The runners are made of maple. When stained, red alder resembles mahogany or walnut. The greater portion of it is used in the manufacture of furniture.

—Photo Courtesy of U. S. Forest Service.

1923, approximately 12 million feet were used for this purpose; the remainder went into miscellaneous products such as woodenware, veneer, fixtures, core stock, handles, laundry appliances, etc. Alder makes excellent charcoal for the manufacture of powder. Experiments conducted by the United States Forest Products laboratory indicate that alder is well adapted to the manufacture of pulp by the soda process, such as is used with aspen, basswood, black cottonwood and other soft deciduous trees.

Black Cottonwood

Black cottonwood, *Populus trichocarpa,* used to rank as the most important hardwood at one time, when it was deemed an essential wood for the manufacture of pulp. However, with the development of the sulphite process whereby the use of western hemlock and white fir was found satisfactory, black cottonwood has been reduced to little importance. It is a tree of comparatively large size, being the giant of the hardwoods of the Pacific coast region. Ordinarily trees are from two to three feet in diameter and about 150 feet tall; exceptional trees have been found up to six feet in diameter and up to 200 feet in height. It is found only at the lower elevations, such as along stream bottoms and the moister situations west of the Cascade range. It is commercially important only in southern British Columbia, western Washington and western Oregon.

The bark of black cottonwood is from $1\frac{1}{2}$ to $2\frac{1}{2}$ inches thick on mature trees, ashy-gray in color, and deeply divided into broadly rounded ridges. The leaves are a dark shiny green upon the upper sides and pale or silvery white underneath; they are rather heart-shaped with an acute point, with finely toothed edges.

The wood is light in weight, dull brown in color with a narrow band of nearly white sapwood. It is not durable, and of little strength, with an even texture. When dry it is soft and has a high shock resistance for

its weight. It is used principally for the manufacture of pulp by the soda process, being mixed with pulp of other species, principally Douglas fir, for the manufacture of higher grades of paper. It is also used for the manufacture of containers where lightness is desirable; also for excelsior, cooperage stock, and core stock for veneers. At the present time the use of black cottonwood is decreasing, mainly because of the scarcity of available timber stands of this species.

Oregon White Oak

Oregon white oak, *Quercus garryana,* is found in considerable quantities in Washington, Oregon and northern California, and to a slight extent on Vancouver Island in British Columbia. It is most abundant in the upper Puget Sound region and on the prairies and bottoms in the Chehalis and Cowlitz valleys in western Washington, and in the Willamette, Umpqua and Rogue river valleys in western Oregon.

Oregon white oak is the only oak in the Pacific Northwest, and is the most important one commercially in the entire Pacific coast region. It attains a size usually from 50 to 60 feet in height and 20 to 30 inches in diameter; exceptional trees are up to 80 or 90 feet tall and three to four feet in diameter. The leaf is the typical oak leaf, quite deeply lobed, 3½ to 6½ inches long, quite thick and somewhat leathery; it is a deep shiny green and smooth on the top side, and pale green and somewhat hairy underneath. The leaves are shed in the autumn of the year. The fruit is an acorn, which is rather sweet, and matures in one season.

The wood is quite similar to the eastern white oak; the heartwood is light yellowish-brown in color, while the narrow sapwood is nearly white. It is heavy, moderately strong, very hard, and has good shock resisting ability. Older trees are inclined to be flinty and brash, making them difficult to work. Second growth timber is softer, more springy and resilient, making it easier to work than older trees. The heartwood is durable when in contact with the soil, and for this reason was largely used for posts in the early days in the northwest. The sapwood is not durable for this purpose in its untreated state.

There has been very little use of Oregon white oak lumber in the past, only about 180,000 board feet being reported in the Oregon wood-using industry for 1923. This was mainly for sash, doors, chairs, plywood, and general millwork. A limited amount is used for handles, as for axe, hammer, hoe, peavy, etc., second growth wood being preferred for this. The wood has a high value as fuel, and large quantities are used for this purpose throughout its range.

Bigleaf Maple

Bigleaf maple, *Acer macrophyllum,* is found over wide range of territory, extending from southeastern Alaska southward along the coast region and the Cascades and Sierras to southern California. Its commercial range, however, is much less in extent, being confined to the stream bottoms and lowlands in western Washington and western Oregon. It is usually found as an incidental tree, in small clumps or isolated individuals, in mixture chiefly with coniferous species. These are mainly Douglas fir, western red cedar, western hemlock, Sitka spruce, and white fir. It is also found to a lesser

extent mixed with red alder, black cottonwood, and Oregon ash.

Only in dense stands does bigleaf maple form a tree which is suitable for lumbering purposes; here it is fairly straight, with a bole well cleared of limbs for 40 or 50 feet above ground, producing a fairly good grade of lumber. Old trees, and trees grown in more open stands, are of large size, but rarely without bad crooks, burls, or other defects. On fairly good soils, and when grown in rather dense stands, bigleaf maple attains a diameter up to about 30 inches, and a height of about 100 feet.

Bigleaf maple obtains its name from its enormous characteristically maple-shaped leaves. These are deeply lobed, and, as a rule, about seven to ten inches wide, with stems from six to 12 inches long. Occasionally large leaves up to 14 to 15 inches in width are found. The fruit, or seed, is produced in large quantities, being composed of a pair of one-winged seeds joined together, but more or less easily separable when mature.

The wood is quite similar to that of the eastern soft maple. It is light pinkish to light brown in color. The grain is straight, usually fine, rather hard, firm, and, as in the case of the eastern maples, curly and birds-eye figures appear. It weighs about the same as the silver and red maples; it is stronger than silver maple, and weaker than either red or sugar maple. In hardness it ranks harder than silver maple and softer than either the red or sugar maple. It is used mainly for furniture manufacture, largely going into lower grade chairs and tables. In addition, considerable maple is manufactured into woodenware, general millwork, brush and broom handles, fixtures, etc. Lately there has been considerable activity in the demand for the curly and birds-eye maple in certain parts of Oregon.

Cascara Sagrada

Cascara sagrada, *Rhamnus purshiana,* although not a timber tree, is of unusual importance in Oregon and Washington for the high value of its bark. Commonly it is known as chittam, cascara, bitterbark, shittimwood and bearberry. The bark is of great value for medicinal purposes.

Cascara is found from British Columbia southward into Lower California, in Mexico; eastward through northern Washington to Idaho and western Montana; also along the eastern slopes of the Sierra Nevada, and into the mountains of Colorado, Arizona, New Mexico and western Texas. The best form of the tree and greatest amounts of cascara are found in the Pacific coast region of Oregon and Washington. Cascara trees grow either singly or in clumps, at rather irregular intervals in the open stands found on old burns or open bottomlands. They show a preference for the deep, rich, loamy soils. The trees are of rather small size, usually not over 30 or 40 feet tall and rarely more than 10 or 12 inches in diameter. Maturity is reached at a rather early age and the life span is estimated at about 50 to 75 years.

The leaves of cascara are longer than broad, rather bluntly pointed, prominently veined, and from about five to eight inches in length. The fruit is a small bluish-black berry, with a juicy, rather thin, sweet-tasting pulp, which contains two or three hard, smooth seeds. The wood is pale yellowish brown, with a faint

tinge of red; moderately soft and heavy; firm, brittle and rather coarse grained. It is of no economic use at the present time.

The bark is of especial value for its medicinal properties, mainly tonic and laxative, and it is collected extensively from trees in the western portions of Oregon and Washington. The money derived from the sale of this bark amounts to a large figure annually, in 1924 the reported cut being about 1500 tons of dried bark.

The peeling of the bark is done from early spring until such a time in the summer when the bark will not peel or "slip" easily. This varies with the weather conditions prevailing throughout the summer. A wet season allows peeling to continue until late in the summer, while in dry years it may be difficult to peel by mid-summer. The trees are first girdled at the ground and the bark is peeled down to this point. As much as possible is peeled while the tree is standing, after which it is cut down and peeling continued in the top and main branches down to about two inches in diameter.

The freshly peeled bark is carried by the peeler or packed on horse to open spaces, where it is spread out upon the ground to dry, the inner side being placed down to keep it clean or from drying too rapidly. In drying out, the bark usually loses about one-half of its green weight. When it has dried sufficiently it is broken into small chunks and placed in burlap sacks for storage until ready to ship. These sacks each contain from 50 to 75 pounds of dried bark.

This industry is the source of considerable revenue to Oregon and Washington, and in view of this, efforts should be made to perpetuate it by obtaining regrowth of the cascara trees. Fire should be kept out of the cascara woods altogether, since fire has no place in any kind of forestry practice. Cascara regenerates itself both from seed and by sprouting from stumps, and observations point to the fact that satisfactory regrowth may be obtained from either source when the cut-over lands are properly handled during the bark-peeling operations by keeping out fires and not destroying young growth which is too small to peel.

Uses of Western Woods

THE principal commercial trees in the forests of western United States are Douglas fir, redwood, western hemlock, western yellow (Pondosa) pine, western (Idaho) white pine, sugar pine, western red cedar, Sitka spruce, western larch, Port Orford cedar, Engelmann spruce, lodgepole pine, and the balsam firs, also called the true firs or white firs. In addition there are a limited number of hardwoods, such as red alder, black cottonwood, bigleaf maple, which, although limited in quantity, are becoming more important as the furniture industry develops in this region.

Some of these species occur in all of these states, as for example Douglas fir, western yellow pine, and lodgepole pine; others are limited to comparatively small areas, such as the Port Orford cedar in the Coos bay region of southwestern Oregon and a small part of northwestern California.

The uses of these different species, due to the qualities in the wood, are quite varied; some, like Douglas fir, being practically "all-purpose" woods, while others, such as Port Orford cedar, are known as "specialty" woods because the latter are adapted to a limited number of uses owing to certain specific qualities of the wood.

All of these woods are adapted to the manufacture of lumber, although some are suited to a wider and more general use for this purpose than others. Other forms of use to which wood is put are the manufacture of pulp, veneers, cooperage stock, piling and poles, railroad ties, which are listed with lumber as primary wood-using industries; and in the secondary wood-using industries as the sash, door, plywood and general millwork, cross arms, wood pipe, tanks and silos, boxes and crates, handles, furniture and fixtures, and other remanufactured products.

Douglas Fir

Pseudotsuga taxifolia

This is one of the most important woods in the United States. As a single species it produces more lumber than any other separate species in the country. The annual consumption is slightly more than 8,000,000,000 board feet.

The principal use to which the wood of this species is put is for lumber, a great deal of it being used for structural purposes. The wood is strong, moderately hard, moderately heavy, and straight grained. Its strength, the large sizes available, and its durability particularly recommend it for all sort of structural uses. About 90 to 95 per cent of the total cut is used for lumber purposes. Other uses to which Douglas fir is adapted are poles and piling (second-growth timber sizes), pulp and paper, veneers and cooperage. Two methods are used in pulp and paper manufacture, both chemical. One, the sulphate method, uses the sawmill refuse for the manufacture of kraft paper, a wrapping paper of great strength; the other, a soda process, which requires a mixture of black cottonwood, produces a high-grade note and book paper.

The principal use of Douglas fir manufactured products is for building materials in the form of sash, doors, flooring, columns and dimension material. A large amount of the lower grades is used for concrete forms for the construction of large buildings. Other uses are for tele-

phone and telegraph cross-arms, tanks, silos, wooden pipes, boxes and crates, woodenware (buckets, tubs, trunks, etc.); also cheaper grades of furniture and fixtures to a certain extent.

Redwood

Sequoia sempervirens

The commercial stands of redwood are limited to the coast regions of northern California and southern Oregon. The wood is light in weight, soft, moderately strong, brittle, with a fine grain which is even and straight. In young trees the rings are wide, with a thin, hard, conspicuously dark-colored summer wood. The sap is thin and nearly white; the heartwood is dark brown. It is very durable under practically all weather conditions, and in contact with the soil.

This wood is used in many forms, and it has an especially high value for uses where durability is essential. For tanks, waterpipes, conduits, flumes, house gutters and shingles where it is exposed to decay producing elements it is unsurpassed and rarely equalled by any other species. Because of this durability redwood makes a good general construction material, as for culverts, trestles and bridges, mud sills, etc. It is also very fire-resistant and has a very low ignition point for wood. Other uses are for general house construction in the form of siding, columns, studding, rafters, etc. For interior finish it is made into celing, panels, moldings, wainscoting, brackets, shelving, etc. In addition considerable redwood is made into sash and doors, furniture, tobacco and fruit boxes, coffins and caskets. Its durability and lightness recommends this wood for railroad ties, but the softness of the wood makes it undesirable where the traffic is heavy. In tropical countries its immunity to white ants makes it a very desirable wood for railroad construction, where they are abundant.

Bigtree

Sequoia washingtoniana

This tree is the giant of all trees, being found on very limited areas on the western slopes of the Sierras in California.

The wood of this species is very light, soft, weak, brittle, coarse-grained, even and straight. The summer wood is dark and conspicuous; the sapwood is white and narrow. The general color is a bright clear red, which turns dark upon exposure. The wood is easily split and easily worked, and is very durable when in contact with the soil.

Because of the limited quantity and that the majority of the trees are under protection in National parks, very little of this species is being cut. The wood is suitable for general lumber purposes, although never used very widely because of its brittleness and general tendency to split into small fragments in the process of lumbering. It has been most widely used for grape stakes, posts, shingles, shakes, siding, framing and rough lumber. Sound lumber made into flumes, conduits and water pipes has proved very satisfactory, and it is also found suitable for the manufacture of lead pencil stock. The amount of lumber cut from this species at the present time is negligible.

Western Hemlock

Tsuga heterophylla

The wood of this species is now generally being marketed as west coast hemlock. In the past it has been sold under various names, or included to an extent with shipments of Douglas fir or Sitka spruce. The

wood is far superior to that of the eastern species of hemlock.

This species produces a wood of most excellent quality. It is moderately strong, ranking second only to Douglas fir in this respect of the Pacific coast softwoods, and moderately light in weight. The grain is usually fine and of even texture, there being little difference between the spring and summer wood. It is soft enough to machine easily, yet of sufficient hardness to wear well. It takes paints, stains and glue well, contains practically no resin, and retains its knots firmly. Hemlock is used largely for rough lumber, dimension, planing mill products, boxes and furniture. A very important use is for pulp and paper manufacture, it now furnishing about 65 per cent of the wood used for this purpose in the Pacific northwest. It is suitable for pulp by both the ground-wood and chemical processes; the former for newsprint, and the latter for note and book papers. Hemlock flooring is meeting with much favor, and when cut vertical grain it is considered as being practically equal in quality to certain eastern hardwoods in smoothness, polishing qualities, and wearing ability. It is also suited for all but the heaviest construction work. However, it is not a durable wood, and when used where this is a factor only such pieces as have been treated with a preservative should be used.

Western Yellow (Pondosa) Pine
Pinus ponderosa

Because the wood of western yellow, or Pondosa, pine is similar in many respects to the white pines, it has often been classed as a white pine; it is the lightest colored and softest textured yellow pine in the United States. In the pine region of Oregon, Washington and Idaho the name Pondosa pine has been adopted by the lumber manufacturers, under which the wood is sold; in California it is sold as California white pine.

This species is the most abundant and most widely used of the western pines in the United States. The wood is moderately light in weight, moderately strong, moderately soft, and usually fine-grained, especially in old trees. The heartwood is reddish-yellow, and the sapwood almost white. In general qualities, such as ease of working, texture, and ability to hold nails, it is an excellent wood, and is substituted for the white pines to a considerable extent for uses requiring these qualities.

In addition to being used for general lumber purposes, western yellow pine is adapted to building construction in the form of sash, doors, flooring, general millwork and rough construction material. As a boxwood it is an outstanding material, and it is especially preferred in the fruit regions of Oregon, Washington and California. A small amount is also used for cheaper grades of furniture, fixtures and kitchen cabinets. It is adapted to the cheaper grades of paper by the sulphite process, but there are no pulp plants in existence using this wood at the present time.

Western (Idaho) White Pine
Pinus monticola

This white pine, in the region of its greatest commercial range and importance, is usually called Idaho white pine. The wood very closely resembles that of the eastern white pine, and the sugar pine of southern Oregon and northern California. It is soft, even-textured and easily worked, and in general has the same physical properties as the eastern white pine. It is rather light in weight, not strong, takes paints, stains

and glue well, and does not split easily in nailing.

The wood is used for general millwork, sash, doors, boxes, crates, woodenware and novelties. It is especially valued very highly for pattern stock. A very important use is for the manufacture of match sticks, a large proportion being used for this purpose. It is also in demand for furniture, drawing boards, cabinet work, siding, ceiling, finish, cases for butter, candy and other foods, boxes and the like.

Sugar Pine

Pinus lambertiana

The commercial range of this species is limited to southern Oregon and northern California. The wood is similar to the other five-needle pines and is used for practically the same purposes. The sapwood and heartwood are well defined, the former is white or yellowish-white, the latter a light brown, which is sometimes tinged with red. It is moderately strong, moderately hard and light in weight when seasoned. The wood is straight grained, moderately coarse, soft and takes a smooth satiny finish. It is easily worked, does not split when nailed, and in general is adapted to the same uses as the eastern and western white pines. In California and Oregon it is used largely for fruit boxes; other products are sash and door stock, furniture, fixtures, pattern stock, matches, cabinets, interior finish and general purposes.

Lodgepole Pine

Pinus contorta

A tree of great potential value in the future is the much despised lodgepole or "jack" pine, which is found over large areas in the western states. Its use at the present time is largely limited to railroad ties, small telephone poles, fence posts, converter poles and fuel wood. Small amounts are manufactured into lumber, boxes and crates. These are usually mixed with other species, principally with western yellow pine, as there is not enough lodgepole pine cut to be sold separately. The wood is whitish in color, with a silvery sheen when smoothed off; the grain is close, even-textured, straight, moderately hard, and takes an excellent polish. Knots are small and tight.

The Spruces

Two species of spruce are found in the Pacific northwest; Sitka spruce, *Picea sitchensis,* and Englemann spruce, *Picea engelmanii.* The Sitka spruce is found only in the low altitudes bordering the Pacific ocean along the lowlands of Oregon, Washington, British Columbia and Alaska. Engelmann spruce is a high altitude tree of the Cascades, the Blue mountains and the Rocky mountains.

The wood of these two spruces is quite similar in character. It is light in weight, moderately soft, straight grained, easily worked, and with great tensile strength for its weight. The heartwood of Sitka spruce is a pale pinkish brown, and the sapwood is creamy white with no decided contrast where the two come together. The wood of Engelmann spruce is white throughout, and is somewhat lower in strength qualities than that of Sitka spruce.

For aircraft purposes Sitka spruce is unsurpassed. Both species are excellent for pulp and paper manufacture. Due to the odorless and tasteless properties of the wood, both species are used to a large extent for food containers. The wood is also very desirable for boxes, crates, barrels, veneers and woodenware because of its ease of working, and ability to take nails without split-

ting. A considerable amount is also used for kitchen cabinets, drain boards, furniture and certain forms of lumber. Due to the weakness of the wood and to its lack of durability, the spruces are not well adapted to heavy construction, or where the wood comes into direct contact with the soil.

Western Red Cedar

Thuya plicata

The wood of red cedar is light in weight, moderately soft, straight grained, and of even texture. It is very resistant to decay, has a distictive aromatic odor, and is practically free from pitch. The sapwood is narrow and nearly white, the heartwood varies from reddish-brown to light yellow.

Red cedar is used for a variety of purposes, but pre-eminently in the manufacture of shingles, about 60 per cent of the total cut being used in this form. It is an excellent wood where lightness and durability, rather than strength, are required. In northeastern Washington and northern Idaho the cedar pole industry is of great importance in furnishing telephone and telegraph poles throughout the country. For this use trees of smaller sizes are in demand, ranging from about 14 to 20 inches in diameter at the butt for average size poles. The lightness and durability of cedar is a big factor in giving this species preference for this purpose. A considerable amount of cedar is also used for wood pipes and water tanks. Other uses are for interior finish, sash and doors, general millwork, small boat construction, woodenware and novelties.

Port Orford Cedar

Chamaecyparis lawsoniana

The wood of this species is known as what is commonly called a specialty wood. Due to the limited stand of this species, and to the high values attached to the wood for certain uses, this is the most valuable tree in point of price in the Pacific coast region. Port Orford cedar is found only in a comparatively limited area from the Coos bay region in Oregon south into northern California, mostly, however, in the state of Oregon. Its commercial zone rarely extends more than 40 or 50 miles inland from the coast line.

The wood is of exceptionally high value. It is light in weight, very fine-grained, faint yellowish-white tinged with red. It is rather hard, firm, easily worked, and very valuable. It is resistant to rot and insects. It is used for battery separators, interior finish, boat construction, pattern stock, veneer, sash and doors, tunnel timbers, railroad ties, furniture, chests, drawers, etc. A large proportion of the better grades of logs and bolts is exported to Japan for house construction, for use as dimension, finish, ceiling and doors. The wood has a very distinctive aromatic odor, which is offensive to certain insects.

Alaska Cedar

Chamaecyparis nootkatensis

Alaska cedar is one of the little-used species at the present time, but prospects are that the wood will be used to a considerable extent as logging operations progress into the forests of this species. Lack of transportation facilities is the greatest handicap in marketing the wood of this cedar. The region of its best development is situated in the Cascades of southern British Columbia and northern Washington, portions of the Olympic Mountains, and the coast regions of British Columbia and Alaska.

The wood of Alaska cedar is com-

paratively hard and heavy for the western cedars. It is rather close-grained, straight, of even texture, splits rather easily, and is comparatively strong. It takes a very smooth finish, and holds stains and paints very well. The wood has a yellowish color, hence it has been called yellow cedar to some extent. It is very durable when exposed to weather, earth or water. Because of its firm qualities, ease of working, and an attractive finish it takes, the wood is especially suitable for interior finish and cabinet work, as well as for special uses requiring softness, lightness, and durability. The principal use at the present time is for the construction of small boats, mainly for the hull and decking.

Incense Cedar

Libocedrus decurrens

The wood of this tree is very light, soft, not strong, brittle, with a fine, even, straight grain and narrow annual rings. The sapwood is nearly white and quite thick; the heartwood is dark brown. It is easily worked on account of its softness and texture, and it is also very durable in contact with the soil. The best incense cedar comes from the western Sierras at an elevation of from 5000 to 6000 feet.

A large proportion of incense cedar is used for fence posts because of its easy splitting habits and its durability. It is also used for interior finish, furniture, lath, shingles, flume construction and general lumber purposes where excessive strength is not required. It has been used for cigar boxes with entire satisfaction.

A serious drawback to the use of this species is the presence of holes in the wood caused by the fungus *Daedalia vorax,* giving the name "pecky cedar" to the wood affected thus. This disease does not appear to affect the durability of the wood, although it greatly reduces its strength.

Western Larch

Larix occidentalis

This tree is the true larch, or tamarack, which is found in the eastern Cascades, Blue mountains, northern Idaho and western Montana. (It should not be confused with the so-called "larch" west of the Cascades, which in reality may be either silver fir, noble fir or the lowland white fir, all of the genus *Abies*).

The wood of larch is moderately heavy, moderately hard and strong, and quite durable. The heartwood is reddish-brown, with a narrow yellowish-white sapwood. The grain is usually straight, and there is a decided contrast between the summer wood and spring wood.

Larch is used for practically all purposes, and due to its strength and durability it is an excellent structural wood. It is used for general building construction, sash and doors, general millwork, flooring and dimension. Large quantities are cut as hewn and sawn ties throughout northeastern Washington, northern Idaho and Montana. Split larch posts are in great demand in the farming regions.

The Balsam Firs

The commercial balsam firs in the Pacific northwest are noble fir, *Abies nobilis,* silver fir, *Abies amabilis,* and lowland white fir, *Abies grandis.* (These are sometimes incorrectly called "larch.") Of these three species noble fir is the most valuable from a lumber standpoint, although the other two undoubtedly will come to greater appreciation as the more easily accessible species are cut out. Silver fir and lowland white fir are valuable for pulp and paper manu-

facture, and are used for this purpose almost exclusively at this time. They are adapted for pulp by either the ground-wood or the sulphite processes. In addition these species are used to some extent for boxes, crates, rough lumber, dimension. Sometimes small amounts of this lumber are included in shipments with other species. Noble fir is a valuable wood for interior finish, sash and doors, general millwork, boxes, woodenware. Its limited range, mostly in the northern Cascades in Oregon and a very small amount in the southern part of Washington, will prevent this species from becoming any great factor in the lumber market.

The Hardwoods

The principal commercial hardwoods of the northwest are red alder, *Alnus rubra,* bigleaf maple, *Acer macrophyllum,* black cottonwood, *Populus trichocarpa,* and Oregon white oak, *Quercus garryana.*

Of these hardwoods red alder is the most used at the present time. When dry the wood is a light yellowish color, has a straight, uniform grain, is moderately light in weight, and rather weak. It turns well and takes a fair polish, and when stained resembles mahogany or walnut. The greatest use is for furniture manufacture and fixtures, about 90 or 95 per cent of the total cut being used for these purposes. Small quantities are manufactured into woodenware and novelties, general millwork, brush and broom handles and miscellaneous articles.

The wood of bigleaf maple is quite similar to the eastern soft maples. It is used mainly for furniture, only a small amount being cut, however. Black cottonwood was once considered an indispensible wood in the pulp industry in the Pacific northwest, but it has been displaced for this purpose by other species due to changes in the methods and processes of pulp manufacture. It is still used to some extent, in mixture with Douglas fir, by the soda process for the manufacture of high-grade note and book papers. In addition small quantities of cottonwood are used for woodenware, excelsior, pails, and novelties. Oregon white oak is quite similar in appearance and hardness to the eastern white oak. Small quantities are cut into sash and door stock.

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